Multiple Stressors in Aquatic Ecosystems: Reference Citations

Adams, S. M. "Biomarker/Bioindicator Response Profiles Of Organisms Can Help Differentiate Between Sources Of Anthropogenic Stressors In Aquatic Ecosystems."** ***BIOMARKERS **6.1 (2001): 33-44.**

Abstract

Aquatic ecosystems can be chronically stressed by multiple environmental factors which originate from a variety of point and non-point sources. In addition, these stressors may vary both spatially and temporally, and, combined with synergestic and cumulative interactions of these stressors, complicate the interpretation and evaluation of stress responses in organisms. To help identify and differentiate between sources of anthropogenic stressors in aquatic systems, a diagnostic approach based on exposure– response pro. les in sentinel organisms was developed from the known effects of various anthropogenic activities on biological systems. To generate these exposure-effects profiles, biomarkers of exposure were plotted against bioindicators of corresponding effects for several major anthropogenic activities including petrochemical, pulp and paper, domestic sewage, mining operations, land-development, and agricultural activities. Biomarkers of exposure to environmental stressors varied widely depending on the type of anthropogenic activity involved. Bioindicator effects, however, including histopathological lesions, bioenergetic status, growth, reproductive impairment, and community-level endpoints were similar among several of the major anthropogenic activities because responses at these higher levels are less specific to stressors than are biomarkers. This approach appears useful for helping to identify and diagnose sources of stress in environments impacted by multiple stressors. By identifying the types and sources of environmental stressors impacting key components of biological systems, aquatic ecosystems can be more effectively protected, regulated, and managed to help improve and maintain environmental quality and ecosystem fitness.

Link

http://informahealthcare.com/doi/pdf/10.1080/135475001452779

Adams, S. M. "Assessing Cause and Effect of Multiple Stressors on Marine Systems"** ***Marine pollution bulletin **51.8-12 (2005): 649-57.**

Abstract

An operational framework is developed to serve as a guideline for investigating causal relationships between environmental stressors and effects on marine biota. Because of the complexity and variability of many marine systems, multiple lines of evidence are needed to understand relationships between stressors and effects on marine resources. Within this framework, a weight of evidence approach based on multiple lines of evidence are developed and applied in a sequential manner by (1) characterizing the study system which involves determining if target biota are impaired, assessment of food and habitat availability, and measuring contaminant levels in the environment, (2) assessing direct effects of contaminant exposure on target biota using biomarkers and assessing indirect effects of exposure using suites of bioindicators, and (3) applying standard causal criteria based on epidemiological principles and diagnostic health profiling techniques to assess potential causes. Use of

multiple lines of evidence should also reduce the risk of false positives (Type I error or falsely concluding that there is a causal relationship when there is none) and false negatives (Type II error or falsely concluding there is not a causal relationship when there actually is). Understanding causal relationships and the mechanistic processes between environmental stressors and effects on biota is important in the effective management and restoration of impaired marine ecosystems.

Link

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V6N-4F29HP1-7&_user=4420&_coverDate=12/31/2005&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1594284478&_rerunOrigin=google&_acct=C000059607&_version=1&_urlVersion=0&_userid=4420&md5=30791057e30dd97df4aa53b300b970f2&searchtype=a

Adams, S. Marshall, M. S. Greeley, and M. G. Ryon. "Evaluating Effects of Contaminants on Fish Health at Multiple Levels of Biological Organization: Extrapolating from Lower to Higher Levels."** ***Human and Ecological Risk Assessment: An International Journal **6.1 (2000): 15 -27.**

Abstract

Effects of environmental stressors such as contaminants on the health of aquatic ecosystems usually involve a series of biological responses ranging from the biomolecular/biochemical to the population and community levels. To establish relationships and to determine the feasibility of extrapolating between higher and lower levels of biological organization, spatial patterns in fish responses to contaminant loading were investigated in a stream receiving point-source discharges of various contaminants near its headwaters. Relationships among fish responses at four major levels of biological organization (biochemical/physiological, individual, population, and community levels) were evaluated relative to patterns in contaminant loading along the spatial gradient of the stream. Both individual and integrated response analysis demonstrated that bioindicators at several levels of biological organization displayed similar downstream patterns in their response to contaminant loading within the stream. Some of the bioindicator responses at lower levels of organization appear to be useful for the ecological risk assessment process because of their sensitivity and apparent relationships to higher levels. By identifying and establishing relationships between levels of biological organization we should be better able to understand the mechanisms of stress responses in ecological systems that could ultimately result in improved predictive capability of ecological risk assessment and also allow for more informed decisions regarding remedial actions.

Link

http://dx.doi.org/10.1080/10807030091124428

Allan, David, Donna Erickson, and John Fay. "The Influence of Catchment Land use on Stream Integrity Across Multiple Spatial Scales." ***Freshwater Biology*** **37.1 (1997): 149-61.**

Abstract

1. Despite wide recognition of the need for catchment-scale management to ensure the integrity of river ecosystems, the science and policy basis for joint management of land and water remains poorly understood. An interdisciplinary case study of a river basin in south-eastern Michigan is presented.

2. The River Raisin drains an area of 2776 km2, of which some 70% is agricultural land. The upper basin consists of till and outwash, and both topography and land use/cover are diverse. The lower basin consists of fine textured lake deposits, is of low relief, and land use is primarily agricultural.

3. The River Raisin basin historically was a region of oak-savannah and wetlands. It was deforested, drained and converted to farmland during the mid-nineteenth century. Human population reached a plateau at about 1880, and then underwent a second period of growth after 1950, mainly in small urban areas. More recently, the amount of agricultural land has declined and forested land has increased, in accord with a general decline in farming activity.

4. It could be suggested that the influence of land use on stream integrity is scale-dependent. Instream habitat structure and organic matter inputs are determined primarily by local conditions such as vegetative cover at a site, whereas nutrient supply, sediment delivery, hydrology and channel characteristics are influenced by regional conditions, including landscape features and land use/cover at some distance upstream and lateral to stream sites.

5. Sediment concentrations measured during low flows were higher in areas of greater agriculture. In a comparison of two subcatchments, sediment yields were up to ten times greater in the more agricultural location, in response to similar storm events. A distributed parameter model linked to a geographical information system predicted that an increase in forested land cover would result in dramatic declines in runoff and sediment and nutrient yields.

6. Habitat quality and biotic integrity varied widely among individual stream sites in accord with patterns in land use/cover. Extent of agricultural land at the subcatchment scale was the best single predictor of local stream conditions. Local riparian vegetation was uncorrelated with overall land use and was a weak secondary predictor of habitat quality and biotic integrity.

7. Investigation of the regulatory agencies involved in land and water management in the basin revealed a complex web of overlapping political jurisdictions. Most land-use decision-making occurs at the local level of township, city or village. Unfortunately, local decision-making bodies typically lack the information and jurisdictional authority to influence up- and downstream events.

Link

http://dx.doi.org/10.1046/j.1365-2427.1997.d01-546.x

Allan, J. D. "Landscapes and Riverscapes: The Influence of Land use on Stream Ecosystems." ***Annual Review of Ecology Evolution and Systematics*** **35 (2004): 257-84.**

Abstract

Local habitat and biological diversity of streams and rivers are strongly influenced by landform and land use within the surrounding valley at multiple scales. However, empirical associations between land use and stream response only varyingly succeed in implicating pathways of influence. This is the case for a number of reasons, including (a) covariation of anthropogenic and natural gradients in the landscape; (b) the existence of multiple, scale-dependent mechanisms; (c) nonlinear responses; and (d) the difficulties of separating present-day from historical influences. Further research is needed that examines responses to land use under different management strategies and that employs response variables that have greater diagnostic value than many of the aggregated measures in current use.

Link

http://www.jstor.org/stable/30034117

Arthington, Angela H., et al. "Preserving the Biodiversity and Ecological Services of Rivers: New Challenges and Research Opportunities."** ***Freshwater Biology **55.1 (2010): 1-16.**

Abstract

1. Natural biogeochemical processes and diverse communities of aquatic biota regulate freshwater quantity and quality in ways that are not sufficiently acknowledged nor appreciated by the water resources management community. The establishment and enforcement of environmental flow requirements offer promising means to improve and care for these critical environmental services. This Special Issue provides new insights and novel techniques to determine, protect and restore ecologically and socially sustainable flow regimes, and thereby help achieve the water-related goals of the Millennium Ecosystem Assessment.

2. Whilst alteration of flow, sediment, organic matter and thermal regimes interact to reduce biological diversity and the ecological integrity of freshwater ecosystems and thereby degrade the properties and ecological services most valued by humans "environmental flows" left in rivers, or restored to developed rivers, will sustain many ecological and societal values. The success of river protection and rehabilitation/restoration depends upon understanding and accurately modeling relationships between hydrological patterns, fluvial disturbance and ecological responses in rivers and floodplains.

3. This Special Issue presents new analytical and modeling approaches to support the development of hydro-ecological models and environmental flow standards at multiple spatial scales applicable to all rivers in any economic and societal setting. Examples include the new framework Ecological Limits of Hydrologic Alteration (ELOHA) founded on hydrological classification and gradient analysis; ecological trait analysis; Bayesian hierarchical modeling; Bayesian Decision Networks; and Integrated Basin Flow Assessment (IBFA).

4. Advances in the allocation of flood flows along the River Murray in Australia, an Ecosystems Function Model (HEC-EFM) for the Bill Williams River restoration program in Arizona (U.S.A), the European Water Framework Directive, and improved management of hydroelectric dams demonstrate the potential for significant ecological recovery following partial restoration of natural river flow regimes.

5. Based on contributions to this Special Issue, the action agenda of the 2007 Brisbane Declaration on environmental flows and the wider literature, we propose an invigorated global research program to construct and calibrate hydro-ecological models and to quantify the ecological goods and services provided by rivers in contrasting hydro-climatic settings across the globe. A major challenge will be to find acceptable ways to manage rivers for multiple uses. Climate change intensifies the urgency. Environmental flows help to preserve the innate resilience of aquatic ecosystems, and thereby offer the promise of improved sustainability and wellbeing for people as well as for ecosystems.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02340.x

Bailey, Robert C., et al. "Integrating Stream Bioassessment and Landscape Ecology as a Tool for Land Use Planning." ***Freshwater Biology*** **52.5 (2007): 908-17.**

Abstract

1. Bioassessment has evolved significantly from a method of deciding whether an ecosystem exposed to stressors should pass or fail (or how badly it fails). Society wants some notion of what has caused any observed degradation of ecosystems, and what management strategies might improve degraded ecosystems. Managers also want to predict what negative or positive effects different land use strategies will have on the component ecosystems of a landscape, including lakes and streams.

2. Here we illustrate an approach to providing these tools to managers with data from a bioassessment study of streams in the Fraser River Basin of British Columbia, Canada.

3. Landscape scale descriptors of both the natural (e.g. catchment size, surficial geology) and stressor (e.g. hard rock mines, forest harvest) environment of each site were used to define the natural and stressor environments of each of the 242 stream sites.

4. We classified 206 reference (relatively unexposed to human activity) sites using their benthic macroinvertebrate community composition, and then discriminated among the

faunally defined groups with landscape scale descriptors of the natural environment of the sites.

5. This discriminant function model allowed us to predict which group each of the test sites would be in if it were in reference condition, and then measure the relationship between the amount of human activity and the biota in each of these groups.

6. These relationships were turned into projections of what will happen to a stream ecosystem's biota if the stressor environment is either improved or degraded. These projection models form the basis of evidence-based land use planning that takes into account the health of freshwater ecosystems.

Link

http://dx.doi.org/10.1111/j.1365-2427.2006.01685.x

Blais, Jules M., et al. "Biologically Mediated Transport of Contaminants to Aquatic Systems." ***Environmental science & technology*** **41.4 (2007): 1075 - 1084.**

Abstract

The prevailing view is that long-range transport of semivolatile contaminants is primarily conducted by the physical system (e.g., winds, currents), and biological transport is typically ignored. Although this view may be correct in terms of bulk budgets and fluxes, it neglects the potential of animals to focus contaminants into foodwebs due to their behaviors and lifecycles. In particular, gregarious animals that biomagnify and bioaccumulate certain contaminants and then migrate and congregate can become the predominant pathway for contaminants in many circumstances. Fish and birds provide prominent examples for such behavior. This review examines the potential for biovector transport to expose populations to contaminants. In addition, we apply a modeling approach to compare the potential of biovector transport to other physical transport pathways for a hypothetical lake receiving large numbers of fish. We conclude that biovector transport should not be neglected when considering environmental risks of biomagnifying contaminants.

Link

http://dx.doi.org/10.1021/es061314a

Boesch, D. "Factors in the Decline of Coastal Ecosystems." ***Science*** **293.5535 (2001): 1589-1591.**

Full Article

In their review "historical overfishing and the recent collapse of coastal ecosystems," Jeremy B. C. Jackson and colleagues argue for the "primacy" of overfishing in the collapse, in contrast to pollution, species introductions, climate change, diseases, and other human

impacts (special issue on Ecology Through Time, 27 Jul., p. 629). They suggest that overfishing had the earliest impacts and was a necessary precondition for the occurrence of other maladies. Although we agree that fishing has contributed to major changes in coastal ecosystems, we believe Jackson and co-authors overstate the case for its primacy. The overfishing and nutrient pollution of coastal seas, for example, have frequently proceeded simultaneously and contributed to degradation synergistically (1). In Chesapeake Bay, as the authors point out, the process of eutrophication began with land clearing in the 18th century, well before the mechanized harvest of oysters in the late 19th century. Although most of the filtration capacity of oyster populations had been reduced by the 1930s, the dramatic intensification of hypoxia and the extensive loss of seagrasses occurred later, during the last half of the 20th century, associated with a more than doubling of the already elevated nitrogen loading (2). Recognizing that rebuilding oyster populations could help to mitigate planktonic overproduction due to nutrient pollution (3), the multistate Chesapeake Bay Program has established the ambitious goal of a 10-fold increase in oyster biomass. But restoration of oysters even to precolonial abundances is unlikely to eliminate algal blooms and hypoxia and recover seagrasses without also significantly reducing nutrient loading. Decreasing bottom-up stimulation and increasing top-down controls will be required. Although the degradation of oyster reefs by overfishing might have made oysters more susceptible to endemic diseases, a particularly virulent pathogen (*Haplosporidum nelsoni*) was introduced from a nonindigenous oyster host in the 1950s (4). This introduced disease now greatly limits the ability to reestablish oyster populations. Similarly, it is not likely that intact populations of large consumers, such as green turtles and sea cows, would have prevented the deleterious consequences of nutrient pollution, sedimentation, and other human-induced stresses on tropical seagrass ecosystems witnessed in the late 20th century in such regions as Australia (5) and Florida Bay (6). And there were no similar large consumers of temperate seagrasses, which have also undergone decline. Regardless of the historical sequence of human stresses, amelioration of multiple stresses must take a multi-pronged approach to restore coastal ecosystems.

Link

http://dx.doi.org/10.1126/science.293.5535.1589c

Böhmer, Jürgen, Claudia Rawer-Jost, and Armin Zenker. "Multimetric Assessment of Data Provided by Water Managers from Germany: Assessment of Several Different Types of Stressors with Macrozoobenthos Communities." *Hydrobiologia* **516.1-3 (2004): 215 - 228.**

Abstract

Our study attempted a new approach to biological assessment in Germany that would comply with the requirements of the European Union Water Framework Directive. We developed a multimetric index for use throughout Germany, based on the macrozoobenthos and devised along the guidelines formulated by Karr & Chu (1999). The index contains twelve measures, chosen for their discriminatory power in assessing general impairment as well as specific stressors (e.g., impoundments, acidification, organic or chemical pollution), the inclusion of all meaningful ecological metric categories, interrelationship as low as

possible and the feasibility of using them in all geographic stream classes of Germany. Due to the availability of data over time the method was developed in three steps. In step 1 we studied the stressor specific response of biological attributes to additional stress by comparing each of 162 sites impaired by a known factor with a nearby site, which was morphologically comparable, but impaired to a lesser extent. The resulting list of 17 candidate metrics for a multimetric index was validated in step 2 using a set of model data from our own investigations. This step included data from not or minimally disturbed reference sites and the design of a five-class-scale of human impact to permit the use of dose-response curves, but no differentiation of stream types. The multimetric index IBI 12 was developed using dose-response curves, correlation coefficients and graphical analysis. The index was improved in the third step, calculations for this based on a dataset containing about 4000 macrozoobentos samples from over 900 streams and rivers in Germany, collected by water management authorities and researchers. The final version of the method uses type specific reference conditions, but the same set of 12 metrics for all stream types. This new IBI 12 is suitable to fulfil the requirements of the EU Water Framework Directive. It correlates with a Spearman's *R* of 0.76 with the general state of impairment for every stream type, and a Spearman's *R* between 0.6 and 0.87 with the most important specific stressors like sewage or morphological degradation. It proved to correlate higher with those stressors than any single index as yet used in Germany. The stressor specific analysis also substantiated that no single metric was really stressor specific with the exception of an acidity index. Even the well established Saprobic indices responded quite well to other stressors besides organic pollution. The results suggest that a separate assessment of specific stressors might be only possible by analysing the reaction pattern of an array of metrics. Further improvement of the index could be achieved by advances in stream typology and the reference conditions, as well as by a higher degree of standardisation to decrease the scatter caused by variations in sampling season, methodology and determination level.

Link

http://www.springerlink.com/content/q44048062124445k/

***Bunn, S. E., et al. "Making the connection between healthy waterways and healthy catchments: South East Queensland, Australia."Web. <http://www98.griffith.edu.au/dspace/bitstream/10072/17939/1/49576_1.pdf> .**

Abstract

The waterways of South East Queensland, Australia, represent unique and complex ecosystems that have a high conservation value and support major recreational and commercial fisheries. The agricultural districts of the region also contribute significantly to the regional economy and, together with the growing urban areas, are heavily reliant on good quality water supplies. However, the human footprint of these activities has led to significant changes in catchment hydrology and sediment delivery, declining water quality and loss of aquatic biodiversity. Predicted population increases in the region are likely to further impact on the ecological and economic health of its waterways and catchments, and there are growing community expectations to reverse the decline in water quality and ecosystem

health. In response to these concerns, government, industry and community stakeholders have worked in close cooperation to develop a whole-of-government, whole-of-community approach to understanding and managing the region's waterways. This paper provides an overview of the experience gained through development of the SEQ Healthy Waterways Partnership and highlights some of the key factors we believe have contributed to its success.

Link

http://www98.griffith.edu.au/dspace/bitstream/10072/17939/1/49576_1.pdf

***Bunn, S. E., et al. "Integration of Science and Monitoring of River Ecosystem Health to Guide Investments in Catchment Protection and Rehabilitation."** *Freshwater Biology* **55 (2010): 223-40.**

Abstract

1. Stream ecosystem health monitoring and reporting need to be developed in the context of an adaptive process that is clearly linked to identified values and objectives, is informed by rigorous science, guides management actions and is responsive to changing perceptions and values of stakeholders. To be effective, monitoring programmes also need to be underpinned by an understanding of the probable causal factors that influence the condition or health of important environmental assets and values. This is often difficult in stream and river ecosystems where multiple stressors, acting at different spatial and temporal scales, interact to affect water quality, biodiversity and ecosystem processes.

2. In this article, we describe the development of a freshwater monitoring programme in South East Queensland, Australia, and how this has been used to report on ecosystem health at a regional scale and to guide investments in catchment protection and rehabilitation. We also discuss some of the emerging science needs to identify the appropriate scale and spatial arrangement of rehabilitation to maximise river ecosystem health outcomes and, at the same time, derive other benefits downstream.

3. An objective process was used to identify potential indicators of stream ecosystem health and then test these across a known catchment land-use disturbance gradient. From the 75 indicators initially tested, 22 from five indicator groups (water quality, ecosystem metabolism, nutrient cycling, invertebrates and fish) responded strongly to the disturbance gradient, and 16 were subsequently recommended for inclusion in the monitoring programme. The freshwater monitoring programme was implemented in 2002, funded by local and State government authorities, and currently involves the assessment of over 120 sites, twice per year. This information, together with data from a similar programme on the region?s estuarine and coastal marine waters, forms the basis of an annual report card that is presented in a public ceremony to local politicians and the broader community.

4. Several key lessons from the SEQ Healthy Waterways Programme are likely to be transferable to other regional programmes aimed at improving aquatic ecosystem health, including the importance of a shared common vision, the involvement of committed

individuals, a cooperative approach, the need for defensible science and effective communication.

5. Thematic implications: this study highlights the use of conceptual models and objective testing of potential indicators against a known disturbance gradient to develop a freshwater ecosystem health monitoring programme that can diagnose the probable causes of degradation from multiple stressors and identify the appropriate spatial scale for rehabilitation or protection. This approach can lead to more targeted management investments in catchment protection and rehabilitation, greater public confidence that limited funds are being well spent and better outcomes for stream and river ecosystem health.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02375.x

Bunn, Stuart E., And Angela H. Arthington. "Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity." ***Environmental management*** **30.4 (2002): 492 -507.**

Abstract

The flow regime is regarded by many aquatic ecologists to be the key driver of river and floodplain wetland ecosystems. We have focused this literature review around four key principles to highlight the important mechanisms that link hydrology and aquatic biodiversity and to illustrate the consequent impacts of altered flow regimes: Firstly, flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biotic composition; Secondly, aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes; Thirdly, maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species; Finally, the invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regimes. The impacts of flow change are manifest across broad taxonomic groups including riverine plants, invertebrates, and fish. Despite growing recognition of these relationships, ecologists still struggle to predict and quantify biotic responses to altered flow regimes. One obvious difficulty is the ability to distinguish the direct effects of modified flow regimes from impacts associated with land-use change that often accompanies water resource development. Currently, evidence about how rivers function in relation to flow regime and the flows that aquatic organisms need exists largely as a series of untested hypotheses. To overcome these problems, aquatic science needs to move quickly into a manipulative or experimental phase, preferably with the aims of restoration and measuring ecosystem response.

Link

http://dx.doi.org/10.1007/s00267-002-2737-0

Burton, G. Allen, and Emma L. Johnston. "Assessing Contaminated Sediments in the Context of Multiple Stressors." *Environmental Toxicology and Chemistry* **29.12 (2010): 2625-43.**

Abstract

Sediments have a major role in ecosystem functioning but can also act as physical or chemical stressors. Anthropogenic activities may change the chemical constituency of sediments and the rate, frequency, and extent of sediment transport, deposition, and resuspension. The importance of sediments as stressors will depend on site ecosystem attributes and the magnitude and preponderance of co-occurring stressors. Contaminants are usually of greater ecological consequence in human-modified, depositional environments, where other anthropogenic stressors often co-occur. Risk assessments and restoration strategies should better consider the role of chemical contamination in the context of multiple stressors. There have been numerous advances in the temporal and spatial characterization of stressor exposures and quantification of biological responses. Contaminated sediments causing biological impairment tend to be patchy, whereas more pervasive anthropogenic stressors, such as alterations to habitat and flow, physical disturbance, and nutrient addition, may drive large-scale ecosystem responses. A systematic assessment of relevant ecosystem attributes and reference conditions can assist in understanding the importance of sediments in the context of other stressors. Experimental manipulations then allow for the controlled study of dominant stressors and the establishment of causal links. This approach will result in more effective management of watersheds and waterways.

Link

http://dx.doi.org/10.1002/etc.332

Carignan, Richard, and Robert J. Steedman. "Impacts of Major Watershed Perturbations on Aquatic Ecosystems." *Canadian Journal of Fisheries and Aquatic Sciences* **57.S2 (2000): 1 - 4.**

Abstract

This Supplement presents data syntheses and new evidence from temperate (primarily boreal) North American studies of aquatic ecosystem response to episodic watershed deforestation and acid rain. These studies confirm the dominant role of the watershed in modulating aquatic response to terrestrial disturbance and quantify important regional differences related to physiography, vegetation, and drainage patterns. Comparisons of watershed disturbance by wildfire and logging revealed both similarities and differences in aquatic impact and underscore the need for ongoing regional evaluation of forest management models based on simulation of natural disturbance patterns. General quantitative impact models are now available but tend to be regional in scope and relevant primarily to water yield and water quality, rather than to habitat and biota.

Link

http://dx.doi.org/10.1139/cjfas-57-s2-1

Carpenter, Stephen R. "Ecological Futures: Building an Ecology of the Long Now." *Ecology* **83.8 (2002): 2069-83.**

Abstract

Ecosystem dynamics unfold into the future but are understood by examining the past. A forward looking ecology, which assesses a broad range of possible future ecosystem states, is the complement of longterm, historical approaches to ecology. Together they are the ecology of the long now. The "long now" of ecosystems includes historical influences that shape present ecologies, and the future consequences of present events. As a step in testing theories by their consequences, prediction is widely used in ecology. Ecologists have developed, criticized, and improved many predictive theories. Ecologists also have developed many empirical relationships that are potentially useful in forecasting. Eutrophication is an example of a problem for which ecologists created fundamental understanding, predictive capability, and new options for management. Ecologists frequently justify their research funding through appeals to improved predictability. This goal is sometimes attainable and in any case motivates a considerable body of insightful research. However, in many cases of environmental decision making, what ecologists cannot predict is at least as important as what can be predicted. It is important to assess the full range of changes in ecosystems that may plausibly occur in the future, and the implications of these changes. The paper discusses some ways that ecological information can be used to improve understanding of the future consequences of present choices.

Link

http://www.esa.org/history/Awards/papers/Carpenter_SR_MA.pdf

***Davies, Bryan R., Martin Thoms, and Michael Meador. "An Assessment of the Ecological Impacts of Inter-Basin Water Transfers, and their Threats to River Basin Integrity and Conservation."** *Aquatic Conservation: Marine and Freshwater Ecosystems* **2.4 (1992): 325-49.**

Abstract

1. Detailed research into the ecological impacts of inter-basin water transfers (IBTs) is virtually nonexistent on a global scale. However, a growing awareness of the serious nature of such impacts for example, the loss of biogeographical integrity, the loss of endemic biotas, the frequent introduction of alien and often invasive aquatic and terrestrial plants and animals, the genetic intermixing of once separated populations, the implications for water quality, the frequently drastic alteration of hydrological regimes, the implications for marine and estuarine processes, climatic effects, and the spread of disease vectors, amongst many others demands a most urgent and world-wide appraisal of all current planning and research strategies.

2. This paper first defines the types of extant IBTs, and details some case studies for three widely separated regions of the world, namely: south-eastern Australia, southern Africa, and the central and south-western parts of the United States of America. In doing so, it highlights the chronic paucity of ecological data on their impacts, while simultaneously emphasising their extreme complexities.

3. Finally, we call for an international meeting on such schemes, as a matter of priority and extreme urgency, in order to assess the extent of IBTs, their geographical distribution, and their ecological and sociological impacts and implications.

Link

http://dx.doi.org/10.1002/aqc.3270020404

Davis, Jenny A., et al. "What Happens When You Add Salt: Predicting Impacts of Secondary Salinisation on Shallow Aquatic Ecosystems by Using an Alternative-States Model " ***Australian Journal of Botany*** **51.6 (2003): 715.**

Abstract

Alternative-states theory commonly applied, for aquatic systems, to shallow lakes that may be dominated alternately by macrophytes and phytoplankton, under clear-water and enriched conditions, respectively, has been used in this study as a basis to define different states that may occur with changes in wetland salinity. Many wetlands of the south-west of Western Australia are threatened by rapidly increasing levels of salinity as well as greater water depths and permanency of water regime. We identified contrasting aquatic vegetation states that were closely associated with different salinities. Salinisation results in the loss of freshwater species of submerged macrophytes and the dominance of a small number of more salt-tolerant species. With increasing salinity, these systems may undergo further change to microbial mat-dominated systems composed mostly of cyanobacteria and halophilic bacteria. The effect of other environmental influences in mediating switches of vegetation was also examined. Colour and turbidity may play important roles at low to intermediate salinities [concentration of total dissolved solids (TDS) <10 000 mg L^{-1}]; however, coloured or turbid wetlands are rarely found at intermediate to high salinities (>10 000 mg L^{-1} TDS). The role of nutrients remains largely unquantified in saline systems. We propose that alternative-states theory provides the basis of a conceptual framework for predicting impacts on wetlands affected by secondary salinisation. The ability to recognise and predict a change in state with changes in salinity adds a further tool to decision-making processes. A change in state represents a fundamental change in ecosystem function and may be difficult to reverse. This information is also important for the development of restoration strategies. Further work is required to better understand the influence of temporal variation in salinity on vegetation states and probable hysteresis effects.

Link

http://dx.doi.org/10.1071/bt02117

Davis, Jenny, Lien Sim, And Jane Chambers. "Multiple Stressors and Regime Shifts in Shallow Aquatic Ecosystems in Antipodean Landscapes." ***Freshwater Biology*** **55 (2010): 5-18.**

Abstract

1. Changes in land management (land use and land cover) and water management (including extraction of ground water and diversion of surface waters for irrigation) driven by increases in agricultural production and urban expansion (and fundamentally by population growth) have created multiple stressors on global freshwater ecosystems that we can no longer ignore.

2. The development and testing of conceptual ecological models that examine the impact of stressors on aquatic ecosystems, and recognize that responses may be nonlinear, is now essential for identifying critical processes and predicting changes, particularly the possibility of catastrophic regime shifts or ecological surprises.

3. Models depicting gradual ecological change and three types of regime shift (simple thresholds, hysteresis and irreversible changes) were examined in the context of shallow inland aquatic ecosystems (wetlands, shallow lakes and temporary river pools) in southwestern Australia subject to multiple anthropogenic impacts (hydrological change, eutrophication, salinisation and acidification).

4. Changes in hydrological processes, particularly the balance between groundwater-dominated versus surface water-dominated inputs and a change from seasonal to permanent water regimes appeared to be the major drivers influencing ecological regime change and the impacts of eutrophication and acidification (in urban systems) and salinisation and acidification (in agricultural systems).

5. In the absence of hydrological change, urban wetlands undergoing eutrophication and agricultural wetlands experiencing salinisation appeared to fit threshold models. Models encompassing alternative regimes and hysteresis appeared to be applicable where a change from a seasonal to permanent hydrological regime had occurred.

6. Irreversible ecological change has potentially occurred in agricultural landscapes because the external economic driver, agricultural productivity, persists independently of the impact on aquatic ecosystems.

7. Thematic implications: multiple stressors can create multiple thresholds that may act in a hierarchical fashion in shallow, lentic systems. The resulting regime shifts may follow different models and trajectories of recovery. Challenges for ecosystem managers and researchers include determining how close a system may be to critical thresholds and which processes are essential to maintaining or restoring the system. This requires an understanding of both external drivers and internal ecosystem dynamics, and the interactions between them, at appropriate spatial and temporal scales.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02376.x

Dewson, Zoë S., Alexander B. W. James, and Russell G. Death. "A Review of the Consequences of Decreased Flow for Instream Habitat and Macroinvertebrates." *Journal of the North American Benthological Society* **26.3 (2007): 401-15.**

Abstract

The effects of drought on stream invertebrates have been reviewed, but the effects of artificially reduced flows have not. We addressed this knowledge gap by reviewing the literature on the effects of natural low flows and artificially reduced flows (without complete cessation of flow). We considered the effects of low water volume on habitat conditions and on invertebrate community structure, behavior, and biotic interactions. Decreases in discharge usually cause decreased water velocity, water depth, and wetted channel width; increased sedimentation; and changes in thermal regime and water chemistry. Invertebrate abundance increases or decreases in response to decreased flow, whereas invertebrate richness commonly decreases because habitat diversity decreases. Invertebrates differ in their environmental tolerances and requirements, and any loss of habitat area or alteration of food resources from decreased flow can influence organism behavior and biotic interactions. Invertebrate drift often increases immediately after flow reduction, although some taxa are more responsive to changes in flow than others. Natural low flows and artificially reduced flows have similar effects on invertebrates, but the severity (duration and magnitude) of the flow decrease can influence invertebrate responses. Certain invertebrate taxa are especially sensitive to flow decreases and might be useful indicators for reduced flows or flow restoration. The effect of low flow on streams is an important issue, but few empirical studies of the impacts of decreased flow on stream ecosystems have been done, and more manipulative experiments are needed to understand the ecological consequences of decreased flow.

Link

http://www.bioone.org/doi/abs/10.1899/06-110.1

***Downes, Barbara J. "Back to the Future: Little-used Tools and Principles of Scientific Inference Can Help Disentangle Effects of Multiple Stressors on Freshwater Ecosystems."** *Freshwater Biology* **55 (2010): 60-79.**

Abstract

1. There are multiple tools for scientific inference that seem rarely used in research examining the effects of stressors on rivers caused by human impacts. Very few of these scientific tools are ?new?. While foundational to scientific methods, they seem to have been overlooked or forgotten. The thesis of this paper is that, by looking back to what used to be considered basic knowledge about scientific methods and the discipline of ecology, we may re-learn some useful ways of improving survey designs and re-framing scientific questions.

2. Two common barriers to strong inference are examined in detail in this paper: disentangling the effects of different stressors, so that we can confidently infer which ones are the causes of unacceptable environmental changes; and dealing with high variability among replicate observations. Poor information about causality means managers cannot know what rehabilitation or amelioration should be attempted. Poor fits of models to data lower confidence in inference. Commonly proffered solutions, which include large sample sizes; choosing ?representative reaches?; or using complex multivariate statistics, do not solve these problems.

3. The solutions lie within the basic components of good experimental design, which apply as much to surveys as they do to experiments. Several pieces of practical advice are offered and explained, which include (i) the necessity to specify a precise mechanism of cause and effect in hypotheses, and what changes to common approaches this entails; (ii) some difficulties caused by scale-ups that are implicit in the selection and measurement of variables, which necessitate changes to some standard protocols; (iii) the value of planned comparisons in surveys as ways of strengthening inference and employing approaches, like control species, where other forms of controls cannot be gained; (iv) the necessity to view random sampling as essential to the selection of sites, which means we should abandon the notion of ?representative? reaches; (v) to use sample compositing and sub-sampling to optimise sampling effort at those replicates that provide degrees of freedom for hypothesis tests while cutting costs (vi) to be open to new forms of analysis, like quantile regression, which tests non-traditional hypotheses about constraints, rather than mean or central responses, and which deals much better with sorting between the effects of multiple stressors.

4. Thematic implications: sorting between the effects of multiple stressors caused by human impacts needs the best possible scientific inference we can apply. Common forms of studies in the modern stream literature suggest we collectively know less now than we did 40?50 years ago because some fundamental aspects of strong inference and basic knowledge in ecology seem to have been forgotten or lost. This raises questions about the quality of ecological training provided at universities. Although some aspects of good design are seen as “too expensive”, cost per se is relative. A well-designed program that has been optimised for the funds available is far cheaper than the costs of poorly designed surveys that provide inaccurate information and predictions, which are more likely to lead to poor management decisions.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02377.x

Dudgeon, David, et al. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." ***Biological Reviews*** **81.2 (2006): 163-82.**

Abstract

Freshwater biodiversity is the over-riding conservation priority during the International Decade for Action –“Water for Life” - 2005 to 2015. Fresh water makes up only 0.01% of

the World's water and approximately 0.8 % of the Earth's surface, yet this tiny fraction of global water supports at least 100 000 species out of approximately 1.8 million - almost 6% of all described species. Inland waters and freshwater biodiversity constitute a valuable natural resource, in economic, cultural, aesthetic, scientific and educational terms. Their conservation and management are critical to the interests of all humans, nations and governments. Yet this precious heritage is in crisis. Fresh waters are experiencing declines in biodiversity far greater than those in the most affected terrestrial ecosystems, and if trends in human demands for water remain unaltered and species losses continue at current rates, the opportunity to conserve much of the remaining biodiversity in fresh water will vanish before the ?Water for Life? decade ends in 2015. Why is this so, and what is being done about it? This article explores the special features of freshwater habitats and the biodiversity they support that makes them especially vulnerable to human activities. We document threats to global freshwater biodiversity under five headings: overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species. Their combined and interacting influences have resulted in population declines and range reduction of freshwater biodiversity worldwide. Conservation of biodiversity is complicated by the landscape position of rivers and wetlands as ?receivers? of land-use effluents, and the problems posed by endemism and thus non-substitutability. In addition, in many parts of the world, fresh water is subject to severe competition among multiple human stakeholders. Protection of freshwater biodiversity is perhaps the ultimate conservation challenge because it is influenced by the upstream drainage network, the surrounding land, the riparian zone, and - in the case of migrating aquatic fauna - downstream reaches. Such prerequisites are hardly ever met. Immediate action is needed where opportunities exist to set aside intact lake and river ecosystems within large protected areas. For most of the global land surface, trade-offs between conservation of freshwater biodiversity and human use of ecosystem goods and services are necessary. We advocate continuing attempts to check species loss but, in many situations, urge adoption of a compromise position of management for biodiversity conservation, ecosystem functioning and resilience, and human livelihoods in order to provide a viable long-term basis for freshwater conservation. Recognition of this need will require adoption of a new paradigm for biodiversity protection and freshwater ecosystem management - one that has been appropriately termed reconciliation ecology.

Link

http://dx.doi.org/10.1017/S1464793105006950

Dyer, Scott D., et al. "Bottom-Up and Top-Down Approaches to Assess Multiple Stressors Over Large Geographic Areas."** ***Environmental Toxicology and Chemistry **19.4 (2000): 1066-75.**

Abstract

The relationship of multiple factors, such as instream habitat, drainage area, gradient, cumulative effluent, conventional pollutants, and chemical mixtures, to fish communities was explored at the subbasin, basin, and state level within the state of Ohio, USA. Two approaches were used: bottom-up, which focused on subbasin- and basin-level relationships within the Great Miami River, Ohio, and top-down, focusing on relationships across the

entire state. Data were provided by the Ohio Environmental Protection Agency and the U.S. Environmental Protection Agency. These data were integrated via a geographical information system. Multiple linear regression was used to determine the strength of stressor-response relationships. The greatest amount of variation of the index of biotic integrity (IBI) and selected metrics was addressed at the subbasin level, followed by the basin and state level, respectively. Overall, habitat factors were the best predictors and positively related to the IBI and number of fish species. Chemical factors, such as cumulative effluent, metals, ammonia, and biochemical oxygen demand, were consistently observed as negative, moderating factors for IBI and fish taxa richness and were the best predictors of the percent of fish observed with deformities, fin erosions, lesions, and tumors.

Link

http://dx.doi.org/10.1002/etc.5620190437

Dynesius, M., and C. Nilsson. "Fragmentation and Flow Regulation of River Systems in the Northern Third of the World. " ***Science (New York, N.Y.)*** **266.5186 (1994): 753-62.**

Abstract

Seventy-seven percent of the total water discharge of the 139 largest river systems in North America north of Mexico, in Europe, and in the republics of the former Soviet Union is strongly or moderately affected by fragmentation of the river channels by dams and by water regulation resulting from reservoir operation, interbasin diversion, and irrigation. The remaining free-flowing large river systems are relatively small and nearly all situated in the far north, as are the 59 medium-sized river systems of Norway, Sweden, Finland, and Denmark. These conditions indicate that many types of river ecosystems have been lost and that the populations of many riverine species have become highly fragmented. To improve the conservation of biodiversity and the sustainable use of biological resources, immediate action is called for to create an international preservation network of free-flowing river systems and to rehabilitate exploited rivers in areas that lack unaffected watercourses.

Link

http://www.sciencemag.org/content/266/5186/753.abstract

European Commission Produced by Working Group 2.3 – REFCOND. ***Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance Document no. 10, Rivers and Lakes – Typology, Reference Conditions and Classification Systems.*** **Office for Official Publications of the European Communities, Luxembourg:, 2003.**

Abstract

This document aims at guiding experts and stakeholders in the implementation of the Directive 2000/60/EC establishing a framework for Community action in the field of water

policy (the Water Framework Directive – "the Directive"). It focuses on the implementation of the Annexes II and V with special emphasis on inland surface waters and methods and principles for the establishment of reference conditions and class boundaries between high, good and moderate ecological status. If this is your task, we believe the Guidance will help you in doing the job, whether you are: x$ Establishing reference conditions and ecological status class boundaries for inland surface waters yourself or participating in the process as a stakeholder; x$ Leading and managing experts undertaking the ecological status analysis; x$ Using the results of the ecological status analysis for taking part to the policy making process; or x$ Reporting on the ecological status analysis to the European Union as required by the Directive.

Link

http://www.wrrl-info.de/docs/Guidance_doc_10_REFCOND_klein.pdf

Fausch, Kurt D., Colden V. Baxter, and Masashi Murakami. "Multiple Stressors in North Temperate Streams: Lessons from Linked Forest-Stream Ecosystems in Northern Japan." ***Freshwater Biology*** **55 (2010): 120-34.**

Abstract

1. Streams are highly connected to their landscapes and so are easily altered by multiple stressors that affect both uplands and riparian zones, and the streams themselves. These include dams and diversions, channelisation, deforestation, water pollution, biological invasions and climate change.

2. We review research conducted in Hokkaido Island, northern Japan, which measured the effects of many of these stressors on both stream food webs and fluxes of invertebrates to and from the riparian zone that feed aquatic and terrestrial consumers. About half the energy that sustains fish falls directly into streams as terrestrial invertebrates, and a quarter of the energy needs for riparian birds is supplied by adult aquatic insects emerging from the stream.

3. Single stressors in these Hokkaido streams, including deforestation, channelisation, erosion-control dams, biological invasions and climate change, have drastic effects on stream food webs, the fishes they support and riparian predators (spiders, birds, and bats). Most stressors caused 30?90% declines in foraging, growth, or abundance of aquatic or terrestrial predators. Indirect effects of stressors also cascaded throughout stream food webs and across the aquatic?terrestrial boundary.

4. Effects of individual stressors were largely concordant across spatial scale, through time during years of different productivity and among different food web components.

5. Two studies of multiple stressors revealed that each stressor alone reduced food web components like abundance of stream benthos or riparian spiders to low levels (35-83% reduction; mean 59%), beyond which an additional stressor had little effect. Synergism and antagonism are less relevant when individual stressors have such large effects.

6. Thematic implications: small streams in Hokkaido are highly sensitive to many individual stressors and have little resistance or resilience to their effects. Moreover, each stressor alone can reduce biota strongly, indicating that restoration will need to consider all simultaneously to protect biotic diversity.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02378.x

Feld, Christian K., And Daniel Hering. "Community Structure or Function: Effects of Environmental Stress on Benthic Macroinvertebrates at Different Spatial Scales." ***Freshwater Biology*** **52.7 (2007): 1380-99.**

Abstract

1. This study investigated the relation of benthic macroinvertebrates to environmental gradients in Central European lowland rivers. Taxonomic structure (taxa) and functional composition (metrics) were related to gradients at four different spatial scales (ecoregion, catchment, reach and site). The environmental variables at the catchment-, reach- and site scales reflected the intensity of human impact: catchment and floodplain land use, riparian and floodplain degradation, flow regulation and river bank and bed modification.

2. Field surveys and GIS yielded 130 parameters characterising the hydromorphology and land use of 75 river sections in Sweden, the Netherlands, Germany and Poland. Two hundred and forty-four macroinvertebrate taxa and 84 derived community metrics and biotic indices such as functional guilds, diversity and composition measures were included in the analysis.

3. Canonical Correspondence Analysis (CCA) and Redundancy Analysis (RDA) showed that hydromorphological and land use variables explained 11.4%, 22.1% and 15.8% of the taxa variance at the catchment ("macro"), reach ("meso") and site ("micro") scales, respectively, compared with 14.9%, 33.2% and 21.5% of the variance associated with the derived metrics. Ecoregion and season accounted for 10.9% and 20.5% of the variance of the taxonomic structure and functional composition, respectively.

4. Partial CCA (pCCA) and RDA (pRDA) showed that the unique variance explained was slightly higher for taxa than for metrics. By contrast, the joint variance explained for metrics was much higher at all spatial scales and largest at the reach scale. Environmental variables explained 46.8% of metric variance and 32.4% of taxonomic structure.

5. Canonical Correspondence Analysis and RDA identified clear environmental gradients along the two main ordination axes, namely, land use and hydromorphological degradation. The impact of catchment land use on benthic macroinvertebrates was mainly revealed by the proportion of urban areas. At the reach scale, riparian and floodplain attributes (bank fixation, riparian wooded vegetation, shading) and the proportion of large woody debris were strong predictors of the taxonomic structure and functional composition of benthic

macroinvertebrates. At the site scale, artificial substrata indicated human impact, particularly the proportion of macro- and mesolithal used for bank enforcement (rip-rap).

6. Our study revealed the importance of benthic macroinvertebrate functional measures (functional guilds, composition and abundance measures, sensitivity and tolerance measures, diversity measures) for detecting the impact of hydromorphological stress at different spatial scales.

Link

http://dx.doi.org/10.1111/j.1365-2427.2007.01749.x

Folt, C. L., et al. "Synergism and Antagonism among Multiple Stressors." *Limnology and Oceanography* **44.3 (1999): 864-77.**

Abstract

This study was designed to test for synergism (increased stress) or antagonism (decreased stress) among multiple environmental stressors using additive, multiplicative, and simple comparative effects models. Model predictions were compared to empirical results of laboratory experiments measuring interactions among thermal stress, toxin exposure, and low food on reproduction and survival of two species of cladoceran zooplankton. Stress was defined operationally as a reduction in reproduction or survival relative to optimal conditions over a 7-d period. These experiments are particularly applicable to episodic stresses such as those associated with short-term heat waves. Toxin or low food in combination with 30 degrees C temperatures were generally more harmful than high temperature alone. However, most multiple stress effects were antagonistic, in that effects in combination were not as severe as predicted based on the sum or the product of their individual effects. In rare cases, interaction among stressors even diminished effects of the worst single stressor. Optimal conditions for reproduction and survival occurred at 25 degrees C, high food and 0 mg liter(-1) toxin (a surfactant, sodium dodecyl sulfate). Suppressive effects of stressors examined individually ranked: high temperature (30 degrees C) > SDS (10 mg liter(-1) greater than or equal to low food (similar to 100 mu g C liter(-1)) > low temperature (20 degrees C). Daphnia pulex isolated from a pond which experiences high summer temperatures throughout was more tolerant of 30 degrees C conditions than Daphnia pulicaria isolated from a lake with a cold-water refuge. Differences were observed in individuals exposed as either adults or as 24-h neonates.

Link

http://academic.research.microsoft.com/Paper/5580200.aspx

Gill, Don. "Modification of Northern Alluvial Habitats by River Development." *Canadian Geographer / Le Géographe canadien* **17.2 (1973): 138-53.**

Abstract

Much public and professional interest has been focused recently on the relationship of environmental problems to northern oil and gas development, and rightly so. However, except for the recent symposium on the Peace-Athabasca Delta (Reinelt et al. 197 1), there is little published information concerning similar problems created by the development of northern rivers. The impoundment of the Peace River by the W. A. C. Bennett Dam, and the subsequent environmental problems experienced downstream in the Peace-Athabasca Delta of northeastern Alberta (Figure 1) , sparked a number of investigations aimed at determining the extent of environmental alterations created by this type of development. Little research of a similar nature has been done in other northern areas, however; thus not much is known about how most alluvial habitats of arctic and subarctic Canada may be degraded by impoundment. The purpose of this paper is thus twofold: 1. To call attention to the environmental alterations that can occur and have already occurred below large storage projects on northern rivers. Floodplains and deltas are most subject to downstream regulation-caused damage; thus they are used as predictive examples. 2. Since northern floodplains and deltas that are undisturbed by man create highly productive habitats that are utilized by a significant number and variety of fish and wildlife, it is argued here that with our increasing manipulation of rivers, fish and wildlife should not be viewed separately from the watersheds that support them; any scheme to dam a northern river should take into account that regulation creates a broad and complex array of mostly detrimental alterations to alluvial habitats. Once this is recognized, planners may then more realistically balance the cost-benefit equation of river development

Link

http://dx.doi.org/10.1111/j.1541-0064.1973.tb00079.x

Gordon, Line J., Garry D. Peterson, and Elena M. Bennett. "Agricultural Modifications of Hydrological Flows Create Ecological Surprises." ***Trends in Ecology & Evolution*** **23.4 (2008): 211-9.**

Abstract

Conclusions and research challenges: There is strong evidence that agricultural modification of water flows can produce a variety of ecological regime shifts that operate across a range of spatial and temporal scales. In a world of growing demands for water, agricultural products and other ecosystem services, there will inevitably be ecological surprises. Preparing for these surprises is essential to maintain ecosystem services of importance for human well-being. Preparation requires understanding the forces that drive these regime shifts, as well as better methods designed specifically to anticipate and analyze them. Identifying ways of building resilience to these shifts illustrates the need to manage agriculture as an embedded part of larger landscapes, with special attention to the internal and external dynamics that drive change in inter-linked agricultural, hydrological and ecological processes. Achieving this will require increased scientific and policy collaborations among ecologists, agronomists, hydrologists and global change researchers.

Link

http://www.sciencedirect.com/science/article/B6VJ1-4S02YVW-5/2/648eb0dd7f963675130749c3456976e6

***Grantham, Theodore E., Adina M. Merenlender, And Vincent H. Resh. "Climatic Influences and Anthropogenic Stressors: An Integrated Framework for Streamflow Management in Mediterranean-Climate California, U.S.A."** *Freshwater Biology* **55 (2010): 188-204.**

Abstract

1. In Mediterranean and other water-stressed climates, water management is critical to the conservation of freshwater ecosystems. To secure and maintain water allocations for the environment, integrated water management approaches are needed that consider ecosystem flow requirements, patterns of human water demands and the temporal and spatial dynamics of water availability.

2. Human settlements in Mediterranean climates have constructed water storage and conveyance projects at a scale and level of complexity far exceeding those in other, less seasonal climates. As a result, multiple ecological stressors associated with natural periods of flooding and drying are compounded by anthropogenic impacts resulting from water infrastructure development.

3. Despite substantial investments in freshwater ecosystem conservation, particularly in California, U.S.A., success has been limited because the scales at which river management and restoration are implemented are often discordant with the temporal and spatial scales at which ecosystem processes operate. Often, there is also strong social and political resistance to restricting water allocation to existing consumptive uses for environmental protection purposes. Furthermore, institutions rarely have the capacity to develop and implement integrated management programmes needed for freshwater ecosystem conservation.

4. We propose an integrated framework for streamflow management that explicitly considers the temporal and spatial dynamics of water supply and needs of both human and natural systems. This approach makes it possible to assess the effects of alternative management strategies to human water security and ecosystem conditions and facilitates integrated decision-making by water management institutions.

5. We illustrate the framework by applying a GIS-based hydrologic model in a Mediterranean-climate watershed in Sonoma County, California, U.S.A. The model is designed to assess the hydrologic impacts of multiple water users distributed throughout a stream network. We analyze the effects of vineyard water management on environmental flows to (i) evaluate streamflow impacts from small storage ponds designed to meet human water demands and reduce summer diversions, (ii) prioritize the placement of storage ponds to meet human water needs while optimizing environmental flow benefits and (iii) examine the environmental and social consequences of flow management policies designed to regulate the timing of diversions to protect ecosystem functions.

6. Thematic implications: spatially explicit models that represent anthropogenic stressors (e.g. water diversions) and environmental flow needs are required to address persistent and growing threats to freshwater biodiversity. A coupled human-natural system approach to water management is particularly useful in Mediterranean climates, characterized by severe competition for water resources and high spatial and temporal variability in flow regimes. However, lessons learned from our analyses are applicable to other highly seasonal systems and those that are expected to have increased precipitation variability resulting from climate change.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02379.x

Greet, Joe, James Webb, and Roger Cousens. "The Importance of Seasonal Flow Timing for Riparian Vegetation Dynamics: A Systematic Review using Causal Criteria Analysis."** ***Freshwater Biology **(in press)**

Abstract

1. Whilst it is widely recognised that a natural flow regime is important for sustaining riverine ecosystems, the relative importance of the various components of flow regime for riparian vegetation dynamics is poorly understood. We sought to determine the current extent of knowledge on the importance of seasonal flow timing for riparian plants by conducting a systematic review of the literature using causal criteria analysis.

2. Using a definition of 'riparian' that includes riverine, wetland and floodplain systems, we found sufficient evidence to provide strong support for the existence of causal relations between seasonal flow timing and a number of riparian plant processes, namely rates of water-borne dispersal (hydrochory), germination and growth, as well as riparian community composition. There was insufficient evidence to infer a causal relationship between flow timing and the reproduction or survival of riparian plants.

3. Thus, we argue that seasonal flow timing is important for many of the processes that generate and sustain riparian vegetation communities. River regulation, and/or flow management aimed at restoring ecological values, should consider flow timing and its implication for riparian flora. Due to regulation, many of the rivers of south-eastern Australia have inverted seasonal flow patterns. Whilst direct evidence of the effects of this inversion on the flora of these rivers is lacking, the results of our causal analysis allow us to predicthow these plant communities may have been affected.

4. However, these predictions must be treated with caution due to the reliance of some of the causal analyses on wetland studies. For riverine flora, further research is particularly needed on the effects of seasonal flow timing on hydrochory, survival and reproduction.

5. Causal criteria analysis provides a defensible and efficient means for assessing the extent of evidence for or against ecological hypotheses of this kind. In this case, systematic review of the literature provided strong evidence to support a number of causal links between

seasonal flow timing and riparian vegetation dynamics, while also efficiently identifying knowledge gaps.

Link

In press (see full PDF)

** --- Gulf of Maine Regional Science Priorities Workshop Impacts of Stressors on Coastal Ecosystem*. **The New England Center Durham, NH. 2009.**

Abstract

The Northeast Sea Grant Programs (NESG), the New Hampshire Sea Grant College Program, the NOAA Center for Sponsored Coastal Ocean Research (CSCOR), and the GOM Regional Ocean Science Initiative sponsored a one-and-a-half-day workshop entitled: Gulf of Maine Regional Science Priorities Workshop: Impacts of Stressors on Coastal Ecosystems. The goal of the workshop was to develop a research agenda for the workshop theme that relates directly to management needs and current critical issues. The products are focused descriptions of several scientific ideas in the form of RFP issue statements and objectives that can help to guide funding agencies in focusing resources for supporting the scientific work required to address regional priorities. The workshop followed the recently released Gulf of Maine Strategic Regional Ocean Science Plan, published through the Gulf of Maine Regional Science Ocean Initiative and supported by the National Sea Grant Office. While the Science Plan identifies a broad range of large regional issues, the purpose of the workshop was to come up with a targeted plan of action for more specific regional issues under the general theme of Impacts on Coastal Ecosystems. Participants included scientists, managers, agency personnel, nongovernmental organizations (NGOs) and others who have knowledge and expertise on specific issues that relate to this theme. Participants also included representatives from funding and advocacy entities who may be able to support the ideas that emerge from the workshop. The following is a summary of the workshop, with details from all discussions and summaries to help move this effort forward. A glossary of acronyms can be found at the end of this document.

Link

http://www.seagrant.unh.edu/GOMworkshopreport.pdf

Harding, Jon S., et al. "Changes in Agricultural Intensity and River Health along a River Continuum." *Freshwater Biology* **42.2 (1999): 345-57.**

Abstract

1. The impact of agricultural activities on waterways is a global issue, but the magnitude of the problem is often not clearly recognized by landowners, and land and water management agencies.

2. The Pomahaka River in southern New Zealand represents a typical lowland catchment with a long history of agricultural development. Fifteen sites were sampled along a 119-km stretch of the river. Headwater sites were surrounded by low-intensity sheep farming, with high-intensity pasture and dairying occurring in the mid-reach and lower reaches.

3. Water clarity decreased significantly from about 6 m in the headwaters to less than 2 m in the lower reaches. Benthic sediment levels increased significantly downriver, peaking at 35 mg m??2 below several tributaries with high-intensity agriculture in their catchments. Periphyton levels were also significantly greater in the lower reaches than the headwaters, and coincided with increased nitrogen (DIN) and phosphorus (SRP) concentrations.

4. Macro-invertebrate species richness did not change significantly throughout the river, but species composition did with Ephemeroptera, and to a lesser extent, Plecoptera and Trichoptera dominating the headwater sites (where there was high water clarity, and low nutrient and periphyton levels). Downriver these assemblages were replaced by molluscs, oligochaetes and chironomids.

5. Canonical correspondence analysis indicated that agricultural intensity and physical conditions associated with agriculture activity (e.g. impacted waters, high turbidity and temperature) were strongly associated with the composition of benthic assemblages at differing reaches down the Pomahaka River.

6. The present results indicate that quantifying agricultural intensity within a catchment, particularly relative livestock densities, may provide a useful tool for identifying threshold levels above which river health declines.

Link

http://dx.doi.org/10.1046/j.1365-2427.1999.444470.x

Hart, Barry T., and Carmel A. Pollino.** ***Bayesian Modeling for Risk-Based Environmental Water Allocation**. 14 Vol. , 2009.**

Abstract

This Waterlines report is part of a series of papers commissioned on issues relating to Australian aquatic ecosystems. These Waterlines reports will contribute to improved environmental water management by stimulating discussion, synthesising current thinking, identifying knowledge gaps and highlighting areas that warrant further investigation. There is a growing recognition that many of Australia's rivers and wetlands are significantly degraded. In an effort to rehabilitate these stressed systems, much effort has been put into reinstating a reasonable environmental flow regime since many of these systems occur where water has been overallocated to consumptive uses. Many of the approaches available in Australia for determining environmental flow allocations suffer from a lack of data, transparency, and knowledge about important aspects of the ecosystem. Additionally, few methods easily account for an adaptive management approach. An adaptive approach is prefereable given our poor knowledge of and the inherent variability in Australian ecosystems. An adaptive

approach for environmental flow assessment and management methods would allow for flow allocations to be refined over time as new information is gained and to account for changes in ecosystems. This report explores the potential for Bayesian modelling approaches (specifically Bayesian networks although Bayesian hierarchical models are considered to a minor extent) to be a key tool in the determination and management of environmental flow allocations. Bayesian approaches are now used in many areas of natural resource management. . . This report summarises the main points to emerge from the review (Henderson et al. 2008, also Appendix A of this report). It provides a short summary of the main discussion points from the workshop and finally provides a set of suggestions to interested parties on a possible way ahead.

Link

http://academic.research.microsoft.com/Paper/5523342.aspx

Hart, David D., and Aram J. K. Calhoun. "Rethinking the Role of Ecological Research in the Sustainable Management of Freshwater Ecosystems."** ***Freshwater Biology **55 (2010): 258-69.**

Abstract

1. Despite the dramatic growth in the understanding of freshwater ecosystems in recent decades, many analyses indicate that the magnitude, complexity and urgency of freshwater environmental problems are increasing rather than decreasing. This pattern serves as a sobering reminder that ecological science is necessary but not sufficient for addressing a wide range of sustainability challenges and suggests the need for alternative strategies that can increase the effectiveness of science in environmental problem solving.

2. One key step in efforts to link knowledge with action more effectively is to use a conceptual model that examines factors leading to mismatches between the demand for science to achieve various societal goals and the supply of scientific information by researchers. Some common examples of supply and demand mismatches include instances where scientific information is provided but not needed, is needed but not provided, is not sufficiently trusted or reliable or conflicts with user's values or interests.

3. Recent work in sustainability science and related fields suggests that such mismatches can be reduced by more careful attention to the design of interdisciplinary research programmes and stakeholder partnerships. For example, research should be salient to the concerns of stakeholders. Research also needs to be independent and objective, so that it is credible to stakeholders. Moreover, researchers should work with stakeholders in ways that foster legitimate decision-making processes. We show how such design criteria can help in identifying and overcoming potential obstacles which limit the influence of ecological research on decision making.

4. These strategies are illustrated by a collaborative programme designed to promote the sustainable management of vernal pools in the northeastern U.S.A. These unique ecosystems are vulnerable to multiple stressors associated with urbanisation, forest management and

climate change. An interdisciplinary team of researchers with a wide array of expertise (e.g., ecology, economics, communication, institutional governance, regional planning and forestry) has established a long-term partnership with multiple levels of government, the private sector, conservation organisations and citizens. Using a variety of approaches for linking knowledge with action, this programme has helped produce new land use regulations and management practices designed to balance economic development and vernal pool protection.

5. Thematic implications: freshwater ecosystems are increasingly impaired by multiple stressors that are usually the product of complex interactions between socioeconomic and biophysical factors. Thus, an understanding of the biophysical causes and consequences of such impairment will rarely be sufficient for achieving sustainable management policies and practices. Rather, we need a more integrative and action-oriented approach that explicitly acknowledges the strong coupling between natural and human systems and focuses on reciprocal interactions between knowledge-generating and decision-making processes. We believe that the emerging field of sustainability science holds considerable promise for strengthening connections between knowledge and action.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02370.x

Hauer, F. Richard, and Mark S. Lorang. "River Regulation, Decline of Ecological Resources, and Potential for Restoration in a Semi-Arid Lands River in the Western USA." ***Aquatic Sciences*** **66.4 (2004): 388 - 401.**

Abstract

Societal needs for power generation, water management/use, and land uses (e.g., urban and agricultural) have often resulted in a significant departure from the natural processes of hydrologic regimes and material transport and deposition throughout most of the rivers flowing through arid and semi-arid landscapes of the western USA. We examine the compromised ecosystem integrity of one such river, the upper Snake River in eastern Idaho, below a large irrigation and power dam that has altered hydrologic regimes and reduced channel sediment supply. We review the ecological structure and function of gravel-bed rivers as they vary across a hierarchy of landscape scales with different spatial and temporal dimensions. Major linkages within the large, alluvial river systems of the western USA include exchange of water and materials along longitudinal connections from streams to rivers, lateral connections between river and floodplain systems, and vertical surface and subsurface (hyporheic) water exchanges. Longitudinal linkages dominate confined (canyon) river reaches while unconfined (floodplain) reaches show strong affinities for lateral and vertical exchange. Hydrogeomorphic processes, driven by river power and cut and fill alluviation, produce a dynamic landscape in floodplain reaches, which we refer to as a Shifting Habitat Mosaic (SHM). The SHM fosters high physical and ecological diversity of habitats, biotic communities, and ecosystem complexity. In this case study, we examine the dynamics of a series of floodplains along a 90 km river landscape, employing an airborne spectrophotometer, producing georeferenced hyperspectral imagery, coupled with ground

truth measures of river hydraulics, river depth, riparian vegetation and other surface characteristics. From these data we derived estimates of the hydraulics and hydrographic regimes necessary to mobilize channel and riparian sediments, thus reestablishing the dynamics of the river SHM. We also evaluated subsequent variation in aquatic and riparian habitat characteristics. Evaluation of these factors, which affect interactions between the river channel and the surrounding river–riparian corridor, permitted us to develop a restoration strategy focused on normative variation among the various physical and biotic processes contributing to ecosystem integrity.

Link

http://dx.doi.org/10.1007/s00027-004-0724-7

Heathwaite, A. L. "Multiple Stressors on Water Availability at Global to Catchment Scales: Understanding Human Impact on Nutrient Cycles to Protect Water Quality and Water Availability in the Long Term."** ***Freshwater Biology **55 (2010): 241-57.**

Abstract

1. Freshwater systems are subject to multiple stressors that include changing climate, changing land use, changing demands on water resources and changing nutrient cycles. Global trends suggest these stressors that impact on water availability will increase over the coming decades, and without action will constrain opportunities to sustain ecosystem services to deliver the Millennium Development Goals.

2. Although a key "service" freshwaters provide is buffering inputs from the land system, predicting ecosystem response through observation and modeling is complex because nonlinear and dynamic interactions amongst a large number of constituents operate to regulate biogeochemical transformations in freshwater systems.

3. Reductionist approaches have been successful at unraveling many of the processes and some of the interactions in freshwater systems. However, reductionist approaches cannot provide the concepts or methods to understand how system properties will emerge in response to a changing climate (particularly the changing spatial and temporal distribution of precipitation); to the consequent change in water availability and water quality in the context of social drivers on the demand for water; and to feedbacks arising from nutrient cycling across a range of scales.

4. This study presents a review of the evidence for landscape-scale filtering of nutrient delivery to receiving waters and examines the role of the internal processing of nutrients at critical interfaces such as the hyporheic in attenuating nutrient loads. Analysis of research on the spatial scales and time step appropriate for catchment and water quality observations indicates the importance of small scale and short time step data for unravelling nutrient cycling in freshwater ecosystems.

5. Thematic implications: leading work in the catchment and aquatic sciences on the importance of diffuse nutrient losses from land, and on nutrient cycling in freshwaters, in governing water quality and protecting water availability, is making an increasing contribution to mainstream environmental science. Critically, the evidence base is starting to grow to inform policy-related debates with respect to food security, to climate change adaptation and for sustaining ecosystem services in freshwater environments.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02368.x

Hecky, R. E., et al. "Multiple Stressors Cause Rapid Ecosystem Change in Lake Victoria." ***Freshwater Biology*** **55 (2010): 19-42.**

Abstract

1. Lake Victoria endured multiple stresses over the past century including population growth, increased cultivation of land, meteorological variability, resource extraction, intensive fishing, introduction of exotic species and more recently climate warming. These stressors became manifest through a fundamental and rapid change in the fish community and fishery in the early 1980s and visible eutrophication. However, the relation of these two phenomena and the possible interaction of the multiple stressors have been difficult to establish because of the temporally fragmented nature of the environmental data.

2. Comprehensive limnological observations from the 1960s were repeated in the 1990s and established the eutrophication of the lake, but these do not provide insight to the time course of when changes in trophic state occurred. Comprehensive fishery catch data from 1965 to the present provide a time course of the change in community composition and yield but cannot be correlated in time with discontinuous and sparse limnological data to determine possible cause-effect relationships.

3. Palaeolimnologic studies were conducted on three cores, two offshore and one nearshore, to establish a time course for the eutrophication of the lake that can be related to time-based data on the fishery. In the 1920s, the cores recorded an increase in nitrogen content of the sediments, but there was no significant response in the paleo-productivity indicators of biogenic Si deposition and change ?13C of deposited organic matter. Phosphorus deposition began to increase in the 1940s in all three cores after which biogenic Si deposition increased steadily over time. Responses in ?13C of organic matter begin in the 1960s at the coring sites. In the 1970s, the 13C of organic matter at the nearshore site increased nearly 3? in a 10-year period likely as a response to a dramatic increase in internal P loading caused by spreading anoxia.

4. Nile perch, the large predatory fish introduced in 1954, had become established through much of the lake at low abundances by the 1970s. In 1980, the catch of this fish began to increase, and by the end of the decade, the Lake Victoria fishery was the largest lake fishery in the world; and Nile perch dominated the catch. While catches of some other fishes also

increased, the endemic haplochromines suffered a catastrophic decline in abundance and loss of biodiversity.

5. The detailed chronostratigraphies for these sediment cores established that the major changes in the trophic condition of the lake were accomplished prior to the change in the fish community and that the increased primary productivity of the lake likely contributed to the increased fish catches after 1980. The increased algal abundance also would have greatly reduced visibility and facilitated the emergence of Nile perch as the dominant top predator.

6. Thematic implications: multiple stresses were present in Lake Victoria over several decades, but transition to a new ecosystem state with a transformed food web and highly productive algal community may have been triggered by a period of low wind stress and then generally warming climate since the 1970s. Unless phosphorus loading is stabilized or reduced, the ecosystem's diversity and balanced productivity will not recover, and other state transitions may occur to the detriment of the lake and its riparian populations.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02374.x

Horsák, Michal, et al. "Impact of Reservoirs and Channelization on Lowland River Macroinvertebrates: A Case Study from Central Europe." ***Limnologica - Ecology and Management of Inland Waters*** **39.2 (2009): 140-51.**

Abstract

In order to assess and compare the ecological impacts of channelization and shallow lowland reservoirs, macroinvertebrate communities of a lowland metapotamal river below reservoirs with epilimnial release were studied. The study was carried out in the Dyje River (Czech Republic) at five sites located from 1.5 to 22.5 km downstream of the reservoir outfall. The five sites differed in the degree of channel modification from natural muddy banks to riprap regulation. Seven samples were collected during the years 1998 and 1999 at each site using a semiquantitative method. The data were processed using multivariate analyses and methods for assessing the ecological and functional structure of communities. Altogether, 261 species of benthic macroinvertebrates were recorded including several rare and threatened taxa. Based on the results of principal component analysis (PCA), most of the variability within the species data (the first PCA axis) was explained by the degree of channel modification, from natural muddy banks with aquatic vegetation to a man-made riprap. The second axis was strongly correlated with current velocity. The sites differed in species richness, total abundances, proportion of individual functional feeding groups, pattern of the distribution of the current preference groups, and values of several biotic indexes, all of which also corresponded to the degree of channel modification. Thus, the morphological man-made modifications of the river channel were found to be the main factor affecting lowland river macroinvertebrates and their biodiversity. Our results suggest that the biggest threat to benthic macroinvertebrate diversity of lowland rivers comes from channelization. The impact of reservoirs can be completely overwhelmed by the impact of channelization,

especially when muddy banks with aquatic vegetation present a substantial part of habitat diversity and significantly contribute to the total species pool.

Link

http://www.sciencedirect.com/science/article/B7GX1-4SNXT2W-1/2/aea3e517adfbb27ddc2000a68f057026

Howarth, R. W., J. R. Fruci, and D. Sherman. "Inputs of Sediment and Carbon to an Estuarine Ecosystem - Influence of Land-use." ***Ecological Applications*** **1.1 (1991): 27-39.**

Abstract

Estuaries and coastal marine ecosystems receive large inputs of nutrients, organic carbon, and sediments from non-point-source runoff from terrestrial ecosystems. In the tidal, freshwater Hudson River estuary, such inputs are the major sources of organic carbon, driving ecosystem metabolism, and thus strongly influencing dissolved oxygen concentrations. We used a watershed simulation model (GWLF) to examine the controls on inputs of organic carbon and sediment to this estuary. The model provides estimates of water discharge, sediment inputs, and organic carbon inputs that agree reasonably well with independent estimates of these fluxes. Even though the watershed for the Hudson River estuary is dominated by forests, the model predicts that both sediment and organic carbon inputs come overwhelmingly from urban and suburban areas and from agricultural fields. Thus changes in land use within the Hudson River basin may be expected to alter inputs to the estuary, thereby altering its metabolism. Precipitation is important in controlling carbon fluxes to the estuary, and so climate change can be expected to alter estuarine metabolism. However, the day-to-day and seasonal patterns of precipitation appear more important than annual mean precipitation in controlling organic carbon fluxes.

Link

http://www.jstor.org/stable/1941845

Hughes, T. P., and J. H. Connell. "Multiple Stressors on Coral Reefs: A Long-Term Perspective." ***Limnology and Oceanography*** **44.3 (1999): 932-40.**

Abstract

Coral reefs are subject to a high frequency of recurrent biological and physical disturbances. The temporal and spatial scales of these are often large and difficult to study, so that most of our knowledge of disturbances on coral reefs comes from investigations conducted at one or a few sites, over shea periods of time. We argue that studying single events in isolation can be misleading and that a longer term approach is necessary for understanding the responses of coral reef assemblages to multiple stressors. We present first a brief review of the impacts of physical disturbance (e.g., cyclones, hurricanes) on the community dynamics of coral reefs, with special attention to the effects of recurrent events. We then examine two

unusually detailed, long-term data sets from Heron Island, Australia, and Jamaica which demonstrate some of the complexities of multiple stressors (broadly defined as natural or man-made disturbances). Both case studies illustrate that the effect of a particular disturbance often depends critically on the impact of previous perturbations. Consequently, even the same type of recurrent stressor can have different effects at different times, depending on history. Accordingly, when the added dimension of time is considered, the distinction between single and multiple stressors becomes blurred. Even a single event such as a hurricane can be viewed mechanistically as a multiple stressor, with short- and long-term impacts. We emphasize that multiple stressors often have significant effects on recruitment and regenerative processes of assemblages. These impacts are much less obvious than catastrophic or chronic mortality, but they play a crucial role in community dynamics over longer time scales. Importantly, chronic anthropogenic impacts can impede the ability of coral assemblages to recover from natural disasters, even where there is little detectable effect on rates of adult mortality. Once a reef has been degraded, it is usually impossible to ascertain retrospectively the precise mechanisms that were involved or the relative importance of different events. A single survey will provide a snapshot of the status of coral reefs, but a longer term approach is required to understand the processes underlying changes in assemblages.

Link

http://www.jstor.org/stable/2670934

Jenkins, K. M., And A. J. Boulton. "Detecting Impacts and Setting Restoration Targets in Arid-Zone Rivers: Aquatic Micro-Invertebrate Responses to Reduced Floodplain Inundation."** ***Journal of Applied Ecology **44.4 (2007): 823-32.**

Abstract

1 .Water extraction from arid-zone rivers increases the time between floods across their floodplain wetlands. Less frequent flooding in Australian arid-zone rivers has impaired waterbird and fish breeding, killed riparian vegetation and diminished invertebrate and macrophyte communities. Restoration currently focuses on reinstating floods to rejuvenate floodplain wetlands, yet indicators to measure the success of this are poorly developed.

2. We explored the application of criteria for ecologically successful river restoration to potential restoration of floodplain wetlands on the Darling River, arid-zone Australia. Using emergence of micro-invertebrates from resting eggs as an indicator, we compared responses of taxa richness, densities and community composition in floodplain lakes with different inundation histories.

3. Increased drying of floodplain lakes reduced the number of micro-invertebrate taxa. Several key taxa were absent and faunal densities (particularly cladocerans) were reduced when the duration of drying increased from 6 to 20 years.

4. A conceptual model of the ecological mechanisms by which restoration of flooding regime could achieve the target of preserving micro-invertebrate community resilience

predicts that reducing the dry period between floods will minimize losses of viable resting eggs. Protection of this "egg bank" permits a boom in micro-invertebrates after flooding, promoting successful recruitment by native fish and waterbirds.

5. Synthesis and applications. In arid-zone rivers, micro-invertebrate densities and community composition are useful indicators of the impact of reduced flooding as a result of water extraction. Critical to successful native fish recruitment as their first feed and as prey for waterbirds, micro-invertebrates are a potential early indicator of responses by higher trophic levels. Taxon richness, density and key taxa present after flooding, all indicators of resilience, can be incorporated into targets for arid-zone river restoration. For example, one restoration target may be microcrustacean densities between 100 and 1000 L-1 within 2-3 weeks after spring flooding. These criteria can be applied to measure the ecological success of restoration projects seeking to recover natural flood regimes. Given the high economic cost of water in arid zones, convincing demonstrations of the ecological success of environmental water allocations are crucial.

Link

http://dx.doi.org/10.1111/j.1365-2664.2007.01298.x

Johnson, L. "Assessing the Effects of Anthropogenic Stressors on Puget Sound Flatfish Populations." ***Journal of Sea Research*** **39.1-2 (1998): 125 - 137.**

Abstract

Puget Sound is an estuary in the northwestern United States which serves as the habitat for a number of recreationally and commercially important species of flatfish. Over the past 100 years, there has been substantial urban and industrial development within this region, resulting in heavy inputs of chemical contaminants at selected sites, as well as significant loss or alteration of marine habitat. Studies show that feral flatfish in Puget Sound are experiencing a range of biological effects due to chemical contaminant exposure, including reproductive dysfunction, altered immune competence, and development of toxicopathic diseases, and there is some evidence of reduced survival in fish from urban areas of Puget Sound from increased infectious and toxicopathic disease. Puget Sound sole are also subject to other anthropogenic stressors, such as fishing pressure or alteration of nearshore nursery habitats. The cumulative impact of these stressors on flatfish abundance in Puget Sound, however, is poorly understood. In a series of field and laboratory studies, we determined vital rates and other life history parameters in English sole (*Pleuronectes vetulus*) subpopulations from urban and non-urban sites in Puget Sound, and are using this information to estimate potential population level impacts of anthropogenic stressors, with age and stage-based Leslie-matrix models. Initial results suggest that declines in the fecundity component of the model, as observed in field studies of fish from contaminated sites, could reduce the size of sub-populations in these areas if the loss of recruits is not offset by density-dependent changes in recruitment, immigration, or other compensating mechanisms. Studies on flatfish species from a variety of sites in Europe and North America suggest that contaminant-related disease and reproductive impairment are widespread in this group of fish, although substantial differences in sensitivity have been observed, even among closely related species.

Comparative studies with a variety of Pleuronectid species will enable us to better evaluate the risk posed by anthropogenic stressors to flatfish, and contribute to improved assessment and management of this important fisheries resource.

Link

http://dx.doi.org/10.1016/s1385-1101(97)00057-9

Johnson, Lucinda, et al. "Landscape Influences on Water Chemistry in Midwestern Stream Ecosystems." ***Freshwater Biology*** **37.1 (1997): 193-208.**

Abstract

Landscape characteristics of sixty-two subcatchments within the Saginaw Bay Catchment of central Michigan were examined to identify relationships with stream water chemistry. Land use, land cover and elevation were quantified for both entire catchments and the upland-river ecotone (100 m stream buffer strip). Catchment and ecotone data were then empirically compared with stream water chemistry using multivariate and regression analyses. Redundancy analysis was used to partition variance among land use, geology, and the shared influence of land use and geology. Strong seasonal differences were observed in total nitrogen and nitrite + nitrate, but not in total phosphorus or suspended solids. Land use and landscape structure factors such as slope and patch density (number of land use patches per km2) accounted for most of the observed variance in summer. In both autumn and summer, landscape factors accounted for much of the observed variation in total dissolved solids and alkalinity. During autumn, geological factors and the shared influence of geology/landscape structure plus land use exerted more influence than did land use alone. Total phosphorus and total suspended solids were much better explained by land use within the stream ecotone in summer than in other seasons. However, total nitrogen, nitrate, orthophosphate and alkalinity were equally well explained by land use within the ecotone and throughout the whole catchment. Only total dissolved solids in summer and ammonium in autumn were explained better by the whole catchment than the ecotone. Our results show that relatively coarse spatial databases can provide useful descriptors of regional water quality.

Link
http://dx.doi.org/10.1046/j.1365-2427.1997.d01-539.x

Kaufman, Les. "Catastrophic Change in Species-Rich Freshwater Ecosystems." ***Bioscience*** **42.11, Stability and Change in the Tropics (1992): pp. 846-858.**

Abstract

After careful consideration of available evidence, based on research results, we conclude that the environment of Lake Victoria is changing rapidly and the fishery is unsustainable at its present composition and yield. Due to overfishing and the development of an export market, the amount of fish protein now available for local consumption is inadequate. The changing condition of the fishery will affect the social and economic welfare of millions of people in the Lake Victoria basin. Prospects for the future are cause for grave concern and

reason for immediate action designed to resolve key unknowns and establish research and management policies that can be developed and applied expeditiously. The resolutions presented below outline the urgent need to understand current changes in limnology and the environment, to understand how fish biology affects the sustainability and management of the fishery, and to understand and mitigate the social and economic impacts of anticipated changes and varied management options. General recommendation It is necessary to form a Lake Victoria Fisheries Commission to harmonize research and management strategies for the Lake Victoria Basin. An important scientific function of the commission should be to foster close international cooperation, standardization of research and management methods, cross-calibration of scientific instruments, and continuity of monitoring. Limnology and environment * There is need to develop a general ecosystems model of Lake Victoria that includes the physical, chemical, biological, and human factors required to understand and predict lake productivity. * Due to increased oxygen depletion, loss of fish habitat and fish kills are extensive. There is urgent need to understand the controls on oxygen distribution and levels in Lake Victoria, including the influence of low levels on fish stocks. * Tremendous alterations in the food web have occurred in the last 30 years. Understanding the effects of these changes on water quality and lake productivity requires determination of the flows of nitrogen, phosphorus, sulfur, silicon, oxygen, and carbon into the lake ecosystem. * There is need to determine the energy flow through the two major trophic pathways (grazing and detritus) that couple fish productivity with primary production. * A research and management program for the wetland and forest habitat in the riparian zone of the lake and its waterways should be undertaken, with special attention to the water hyacinth.

Link

http://www.jstor.org/stable/1312084

Kennard, M. J., et al. "Are Alien Fish a Reliable Indicator of River Health?" *Freshwater Biology* **50.1 (2005): 174-93.**

Abstract

1. The ability of many introduced fish species to thrive in degraded aquatic habitats and their potential to impact on aquatic ecosystem structure and function suggest that introduced fish may represent both a symptom and a cause of decline in river health and the integrity of native aquatic communities.

2. The varying sensitivities of many commonly introduced fish species to degraded stream conditions, the mechanism and reason for their introduction and the differential susceptibility of local stream habitats to invasion because of the environmental and biological characteristics of the receiving water body, are all confounding factors that may obscure the interpretation of patterns of introduced fish species distribution and abundance and therefore their reliability as indicators of river health.

3. In the present study, we address the question of whether alien fish (i.e. those species introduced from other countries) are a reliable indicator of the health of streams and rivers

in south-eastern Queensland, Australia. We examine the relationships of alien fish species distributions and indices of abundance and biomass with the natural environmental features, the biotic characteristics of the local native fish assemblages and indicators of anthropogenic disturbance at a large number of sites subject to varying sources and intensities of human impact.

4. Alien fish species were found to be widespread and often abundant in south-eastern Queensland rivers and streams, and the five species collected were considered to be relatively tolerant to river degradation, making them good candidate indicators of river health. Variation in alien species indices was unrelated to the size of the study sites, the sampling effort expended or natural environmental gradients. The biological resistance of the native fish fauna was not concluded to be an important factor mediating invasion success by alien species. Variation in alien fish indices was, however, strongly related to indicators of disturbance intensity describing local in-stream habitat and riparian degradation, water quality and surrounding land use, particularly the amount of urban development in the catchment.

5. Potential confounding factors that may influence the likelihood of introduction and successful establishment of an alien species and the implications of these factors for river bioassessment are discussed. We conclude that the potentially strong impact that many alien fish species can have on the biological integrity of natural aquatic ecosystems, together with their potential to be used as an initial basis to find out other forms of human disturbance impacts, suggest that some alien species (particularly species from the family Poeciliidae) can represent a reliable "first cut" indicator of river health.

Link

http://dx.doi.org/10.1111/j.1365-2427.2004.01293.x

Kennedy, V. S. "Anticipated Effects of Climate Change on Estuarine and Coastal Fisheries." ***Fisheries*** **15.6 (1990): 16-24.**

Abstract

Although the timing and magnitude of global climate change is in dispute, the possible effects of such change merit consideration to allow for discussion of policy ramifications and mitigative actions. Climate change may result in sea level rise; water temperature increase; and deviations from present patterns of precipitation, wind, and water circulation. Estuaries may experience loss of marsh habitat, intrusion of marine waters and associated organisms, changes in circulation patterns that affect retention of some indigenous species, and increased hypoxia and storm surges. Estuarine and coastal systems could experience poleward retreat of cold-tolerant species and range expansion of warm-tolerant species. Some fisheries and aquacultural enterprises and communities would benefit from the results of climate change and other would suffer losses, with economic and population dislocations probably inevitable in many parts of the world. Thus, flexibility in policy-making and planning will be vital if global climate is modified as rapidly as is anticipated by some scientists.

Link

http://afsjournals.org/doi/abs/10.1577/1548-8446(1990)015%3C0016%3AAEOCCO%3E2.0.CO%3B2

Laeser, Scott R., Colden V. Baxter, and Kurt D. Fausch. "Riparian Vegetation Loss, Stream Channelization, and Web-Weaving Spiders in Northern Japan." *Ecological Research* **20.6 (2005; 2005): 646- 651.**

Abstract

Removal of riparian vegetation and straightening of stream channels (channelization) are the most prevalent forms of habitat degradation in streams and their riparian zones. Both have direct effects on organisms in the habitats where they occur, but also have potential to cause indirect effects by interrupting the flux of invertebrate prey between the two adjacent ecosystems. We measured abundance of web-building riparian spiders along four types of streams in Hokkaido, Japan: relatively undisturbed streams, streams where riparian vegetation had been removed, previously channelized streams where the banks had revegetated, and streams that had been both channelized and had the vegetation removed. Spider abundance was reduced by 70% or more by either habitat disturbance alone, or both combined, and the number of spider families was also reduced. Spiders of the family Tetragnathidae, which specialize in capturing adult insects emerging from streams, were strongly reduced by either form of habitat degradation alone, or in combination. In contrast, abundance of spiders in other families that capture prey from both terrestrial and aquatic sources was reduced more strongly by vegetation loss than channelization. These results indicate that riparian vegetation loss has strong direct effects on spiders by reducing habitat for web sites. They also suggest that channelization can have strong indirect effects on riparian-specialist tetragnathid spiders, probably by reducing the flux of adult aquatic insects from the stream to the riparian zone.

Link

http://www.springerlink.com/content/h5840520597j5423/

Lavé, J. "Denudation Processes and Rates in the Transverse Ranges, Southern California: Erosional Response of a Transitional Landscape to External and Anthropogenic Forcing." *Journal of Geophysical Research* **109.F1 (2004)**

Abstract

Quantification of denudation in the Transverse Ranges of California permits reconstruction of spatial and temporal variations in erosion that represent both the response and evolution of interacting hillslopes and channels. On the southern front of the San Gabriel Mountains, observational records of the infilling of debris basins and dams define twentieth-century landscape erosion rates averaging 1.6 and 0.9 mm yr^{-1}, respectively. Although all major sediment transport occurs during intense winter storms, debris production on hillslopes is greatly enhanced by recurrent fires. Consequently, in this populated region, anthropogenic

fires have augmented the natural erosion rates. We perform a global inversion to estimate the role of precipitation intensity, burned areas, and local slope on catchment denudation rates. After subtracting the effects of anthropogenic fires we estimate landscape denudation rates given natural fire ignition rates. Increased fire during the past century has augmented sediment production in debris basins by an average of ≥60%, and individual basins show increases up to 400%. To identify the dominant hillslope erosion processes, the volumetric contribution of landslides was estimated using repeat aerial photographs for the same time interval over which the debris basins have been operative. Between 1928 and 1973, landsliding produced only ~10% of the sediment in debris basins. Even in the long term, when infrequent but volumetrically important landslides occur, bedrock landslides appear to contribute a maximum of 50% to the long-term landscape denudation. Previous mapping of soil slippage in the San Dimas Experimental Forest within the San Gabriel Mountains [*Rice et al.*, 1969 ; *Rice and Foggin*, 1971] indicates that shallow landsliding is likely to be the dominant modern hillslope erosion process. When compared to incision rates derived from a fluvial shear stress model and to exhumation rates based on low-temperature thermochronological data [*Blythe et al.*, 2000], modern "natural" erosion rates are comparable to denudation rates since the Pliocene. Comparisons of modern erosion rates suggest that debris production on hillslopes and first-order channels is directly dependent on vegetation cover and precipitation intensity. For higher-order channels (drainage areas >2 km^2), only major storms convey the sediments down valley. During the past century, some temporal decorrelation occurs between small-scale and large-scale catchments because hillslope-produced sediment is stored in second-order and higher channels until major storms mobilize it. Thus the larger fluvial network damps the episodic, fire-induced hillslope sediment pulses that occur within small watersheds. At a longer temporal scale, however, uplift and denudation may have been sustained sufficiently long in much of the San Gabriel Mountains for the topography to reach a macroscale steady state. In contrast to rapidly eroding (≥2 mm yr^{-1}) ranges, for which quantification of bedrock landsliding will approximate the sediment flux, the San Gabriel Mountains occupy a niche of intermediate rates (0.1–1.0 mm yr^{-1}) in which a broad suite of hillslope processes, including shallow-seated and deep-seated landslides, debris flows, and wet and dry ravel, contribute to the sediment flux.

Link

http://dx.doi.org/10.1029/2003jf000023

Likens, Gene E., et al. "Effects of Forest Cutting and Herbicide Treatment on Nutrient Budgets in the Hubbard Brook Watershed-Ecosystem." ***Ecological Monographs*** **40.1 (1970): pp. 23-47.**

Abstract

All vegetation on Watershed 2 of the Hubbard Brook Experimental Forest was cut during November and December of 1965, and vegetation regrowth was inhibited for two years by periodic application of herbicides. Annual stream-flow was increased 33 cm or 39% the first year and 27 cm or 28% the second year above the values expected if the watershed were not deforested. Large increases in streamwater concentration were observed for all major ions,

except NH"4+, SO"4 = and HCO"3^-, approximately five months after the deforestation. Nitrate concentrations were 41-fold higher than the undisturbed condition the first year and 56-fold higher the second. The nitrate concentration in stream water has exceeded, almost continuously, the health levels recommended for drinking water. Sulfate was the only major ion in stream water that decreased in concentration after deforestation. An inverse relationship between sulfate and nitrate concentrations in stream water was observed in both undisturbed and deforested situations. Average streamwater concentrations increased by 417% for Ca^+^+, 408% for Mg^+^+, 1558% for K^+ and 177% for Na^+ during the two years subsequent to deforestation. Budgetary net losses from Watershed 2 in kg/ha-yr were about 142 for NO"3-N, 90 for Ca^+^+, 36 for K^+, 32 for SiO"2-Si, 24 for Al^+^+^+, 18 for Mg^+^+, 17 for Na^+, 4 for Cl^-, and 0 for SO"4-S during 1967-68; whereas for an adjacent, undisturbed watershed (W6) net losses were 9.2 for Ca^+^+, 1.6 for K^+, 17 for SiO"2-Si, 3.1 for A1^+^+^+, 2.6 for Mg^+^+, 7.0 for Na^+, 0.1 for C1^-, and 3.3 for SO"4-S. Input of nitrate-nitrogen in precipitation normally exceeds the output in drainage water in the undisturbed ecosystems, and ammonium-nitrogen likewise accumulates in both the undisturbed and deforested ecosystems. Total gross export of dissolved solids, exclusive of organic matter, was about 75 metric tons/km^2 in 1966-67, and 97 metric tons/km^2 in 1967-68, or about 6 to 8 times greater than would be expected for an undisturbed watershed. The greatly increased export of dissolved nutrients from the deforested ecosystem was due to an alteration of the nitrogen cycle within the ecosystem. The drainage streams tributary to Hubbard Brook are normally acid, and as a result of deforestation the hydrogen ion content increased by 5-fold (from pH 5.1 to 4.3). Streamwater temperatures after deforestation were higher than the undisturbed condition during both summer and winter. Also in contrast to the relatively constant temperature in the undisturbed streams, streamwater temperature after deforestation fluctuated 3-4@?C during the day in summer. Electrical conductivity increased about 6-fold in the stream water after deforestation and was much more variable. Increased streamwater turbidity as a result of the deforestation was negligible, however the particulate matter output was increased about 4-fold. Whereas the particulate matter is normally 50% inorganic materials, after deforestation preliminary estimates indicate that the proportion of inorganic materials increased to 76% of the total particulates. Supersaturation of dissolved oxygen in stream water from the experimental watersheds is common in all seasons except summer when stream discharge is low. The percent saturation is dependent upon flow rate in the streams. Sulfate, hydrogen ion and nitrate are major constituents in the precipitation. It is suggested that the increase in average nitrate concentration in precipitation compared to data from 1955-56,as well as the consistent annual increase observed from 1964 to 1968, may be some measure of a general increase in air pollution.

Link

http://www.jstor.org/stable/1942440

Lotze, H. K., et al. "Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas " *Science (New York, N.Y.)* 312.5781 (2006): 1806-9.

Abstract

Estuarine and coastal transformation is as old as civilization yet has dramatically accelerated over the past 150 to 300 years. Reconstructed time lines, causes, and consequences of change in 12 once diverse and productive estuaries and coastal seas worldwide show similar patterns: Human impacts have depleted >90% of formerly important species, destroyed >65% of seagrass and wetland habitat, degraded water quality, and accelerated species invasions. Twentieth-century conservation efforts achieved partial recovery of upper trophic levels but have so far failed to restore former ecosystem structure and function. Our results provide detailed historical baselines and quantitative targets for ecosystem-based management and marine conservation.

Link

www.lenfestocean.org/publications/Lotze-etal_06_Science.pdf

Lotze, Heike K., and Inka Milewski. "Two Centuries of Multiple Human Impacts and Successive Changes in a North Atlantic Food Web." ***Ecological Applications*** **14.5 (2004): 1428- 1447.**

Abstract

European colonization of North America severely altered terrestrial and aquatic ecosystems alike. Here, we integrate archaeological, historical, and recent data to derive the ecological history of the Quoddy Region, Bay of Fundy, Canada, an upwelling region rich in marine diversity and productivity. We document successive changes on all trophic levels from primary producers to top predators over the last centuries. Our objectives were to (1) construct a baseline of "what was natural in the coastal ocean," and (2) analyze the sequence and potential interaction of multiple human impacts.

Link

http://www.esajournals.org/doi/abs/10.1890/03-5027

Mazor, Raphael D., Alison H. Purcell, and Vincent H. Resh. "Long-Term Variability in Bioassessments: A Twenty-Year Study from Two Northern California Streams." ***Environmental Management (2009) 43:1269–1286*** **43 (2009): 1296.**

Abstract

Long-term variability of bioassessments has not been well evaluated. We analyzed a 20-year data set(1984–2003) from four sites in two northern California streams to examine the variability of bioassessment indices(two multivariate RIVPACS-type O/E scores and one multimetric index of biotic integrity, IBI), as well as eight metrics. All sites were sampled in spring; one site was also sampled in summer. Variability among years was high for most metrics (coefficients of variation, CVs ranging from16% to 246% in spring) but lower for indices (CVs of 22–26% for the IBI and 21–32% for O/E scores in spring), which resulted in inconsistent assessments of biological condition. Variance components analysis showed that the time component explained variability in all metrics and indices, ranging from 5% to

35% of total variance explained. The site component was large (i.e.,[40%) for some metrics (e.g., EPT richness), but nearly absent from others (e.g., Diptera richness). Seasonal analysis at one site showed that variability among seasons was small for some metrics or indices (e.g., Coleoptera richness), but large for others (e.g., EPT richness, O/E scores). Climatic variables did not show consistent trends across all metrics, although several were related to the El Nin˜o Southern Oscillation Index at some sites. Bioassessments should incorporate temporal variability during index calibration or include climatic variability as predictive variables to improve accuracy and precision. In addition, these approaches may help managers anticipate alterations in reference streams caused by global climate change and high climatic variability.

Link

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/586_LongTermVariability.pdf

McCabe, D. J., and N. J. Gotelli. "Effects of Disturbance Frequency, Intensity, and Area on Assemblages of Stream Macroinvertebrates." ***Oecologia*** **124.2 (2000): 270 - 279.**

Abstract

Disturbance frequency, intensity, and areal extent may influence the effects of disturbance on biological communities. Furthermore, these three factors may have interacting effects on biological diversity. We manipulated the frequency, intensity, and area of disturbance in a full-factorial design on artificial substrates and measured responses of benthic macroinvertebrates in a northern Vermont stream. Macroinvertebrate abundance was lower in all disturbance treatments than in the undisturbed control. As in most other studies in streams, species density (number of species/sample) was lower in disturbed treatments than in undisturbed controls. However, species density is very sensitive to total abundance of a sample, which is usually reduced by disturbance. We used a rarefaction method to compare species richness based on an equivalent number of individuals. In rarefied samples, species richness was higher in all eight disturbed treatments than in the undisturbed control, with significant increases in species richness for larger areas and greater intensities of disturbance. Increases in species richness in response to disturbance were consistent within patches, among patches with similar disturbance histories, and among patches with differing disturbance histories. These results provide some support for Huston's dynamic-equilibrium model but do not support the intermediate-disturbance hypothesis. Our analyses demonstrate that species richness and species density can generate opposite patterns of community response to disturbance. The interplay of abundance, species richness, and species density has been neglected in previous tests of disturbance models.

Link

http://dx.doi.org/10.1007/s004420000369

McClure, Michelle M., et al. "Evolutionary Consequences of Habitat Loss for Pacific Anadromous Salmonids." ***Evolutionary Applications*** **1.2 (2008): 300-18.**

Abstract

Large portions of anadromous salmonid habitat in the western United States has been lost because of dams and other blockages. This loss has the potential to affect salmonid evolution through natural selection if the loss is biased, affecting certain types of habitat differentially, and if phenotypic traits correlated with those habitat types are heritable. Habitat loss can also affect salmonid evolution indirectly, by reducing genetic variation and changing its distribution within and among populations. In this paper, we compare the characteristics of lost habitats with currently accessible habitats and review the heritability of traits which show correlations with habitat/environmental gradients. We find that although there is some regional variation, inaccessible habitats tend to be higher in elevation, wetter and both warmer in the summer and colder in the winter than habitats currently available to anadromous salmonids. We present several case studies that demonstrate either a change in phenotypic or life history expression or an apparent reduction in genetic variation associated with habitat blockages. These results suggest that loss of habitat will alter evolutionary trajectories in salmonid populations and Evolutionarily Significant Units. Changes in both selective regime and standing genetic diversity might affect the ability of these taxa to respond to subsequent environmental perturbations. Both natural and anthropogenic and should be considered seriously in developing management and conservation strategies.

Link

http://dx.doi.org/10.1111/j.1752-4571.2008.00030.x

Menzie, C. A., M. M. MacDonell, and M. Mumtaz. "A Phased Approach for Assessing Combined Effects from Multiple Stressors "** ***Environmental Health Perspectives **115.5 (2007): 807-16.**

Abstract

We present a phased approach for evaluating the effects of physical, biological, chemical, and psychosocial stressors that may act in combination. Although a phased concept is common to many risk-based approaches, it has not been explicitly outlined for the assessment of combined effects of multiple stressors. The approach begins with the development of appropriate conceptual models and assessment end points. The approach then proceeds through a screening stage wherein stressors are evaluated with respect to their potential importance as contributors to risk. Stressors are considered individually or as a combination of independent factors with respect to one or more common assessment end points. As necessary, the approach then proceeds to consider interactions among stressors. We make a distinction between applications that begin with effects of concern (effects based) or with specific stressors (stressor based). We describe a number of tools for use within the phased approach. The methods profiled are ones that have been applied to yield results that can be communicated to a wide audience. The latter characteristic is considered

especially important because multiple stressor problems usually involve exposures to communities or to ecologic regions with many stakeholders.

Link

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1868003/

Micheli, F. "Eutrophication, Fisheries, and Consumer-Resource Dynamics in Marine Pelagic Ecosystems." ***Science*** **285.5432 (1999): 1396 - 1398.**

Abstract

Anthropogenic nutrient enrichment and fishing influence marine ecosystems worldwide by altering resource availability and food-web structure. Meta-analyses of 47 marine mesocosm experiments manipulating nutrients and consumers, and of time series data of nutrients, plankton, and fishes from 20 natural marine systems, revealed that nutrients generally enhance phytoplankton biomass and carnivores depress herbivore biomass. However, resource and consumer effects attenuate through marine pelagic food webs, resulting in a weak coupling between phytoplankton and herbivores. Despite substantial physical and biological variability in marine pelagic ecosystems, alterations of resource availability and consumers result in general patterns of community change.

Link

http://dx.doi.org/10.1126/science.285.5432.1396

Moore, Marianne V., et al. "Potential Effects of Climate Change on Freshwater Ecosystems of the New England/Mid-Atlantic Region." ***Hydrological Processes*** **11.8 (1997): 925-47.**

Abstract

Numerous freshwater ecosystems, dense concentrations of humans along the eastern seaboard, extensive forests and a history of intensive land use distinguish the New England/Mid-Atlantic Region. Human population densities are forecast to increase in portions of the region at the same time that climate is expected to be changing. Consequently, the effects of humans and climatic change are likely to affect freshwater ecosystems within the region interactively. The general climate, at present, is humid continental, and the region receives abundant precipitation. Climatic projections for a 2 × CO2 atmosphere, however, suggest warmer and drier conditions for much of this region. Annual temperature increases ranging from 3?5°C are projected, with the greatest increases occurring in autumn or winter. According to a water balance model, the projected increase in temperature will result in greater rates of evaporation and evapotranspiration. This could cause a 21 and 31% reduction in annual stream flow in the southern and northern sections of the region, respectively, with greatest reductions occurring in autumn and winter. The amount and duration of snow cover is also projected to decrease across the region, and summer convective thunderstorms are likely to decrease in frequency but increase in

intensity. The dual effects of climate change and direct anthropogenic stress will most likely alter hydrological and biogeochemical processes, and, hence, the floral and faunal communities of the region's freshwater ecosystems. For example, the projected increase in evapotranspiration and evaporation could eliminate most bog ecosystems, and increases in water temperature may increase bioaccumulation, and possibly biomagnification, of organic and inorganic contaminants. Not all change may be adverse. For example, a decrease in runoff may reduce the intensity of ongoing estuarine eutrophication, and acidification of aquatic habitats during the spring snowmelt period may be ameliorated. Recommendations for future monitoring efforts include: (1) extending and improving data on the distribution, abundance and effect of anthropogenic stressors (non-point pollution) within the region; and (2) improving scientific knowledge regarding the contemporary distribution and abundance of aquatic species. Research recommendations include: (1) establishing a research centre(s) where field studies designed to understand interactions between freshwater ecosystems and climate change can be conducted; (2) projecting the future distribution, activities and direct effects of humans within the region; (3) developing mathematical analyses, experimental designs and aquatic indicators that distinguish between climatic and anthropogenic effects on aquatic systems; (4) developing and refining projections of climate variability such that the magnitude, frequency and seasonal timing of extreme events can be forecast; and (5) describing quantitatively the flux of materials (sediments, nutrients, metals) from watersheds characterized by a mosaic of land uses.

Link

http://dx.doi.org/10.1002/(SICI)1099-1085(19970630)11:8<925::AID-HYP512>3.0.CO;2-X

Moss, Brian. "Climate Change, Nutrient Pollution and the Bargain of Dr Faustus."** ***Freshwater Biology **55 (2010): 175-87.**

Abstract

1. The legend of Dr Faustus crops up repeatedly in European literature, drama and music, suggesting that it has profound meaning. In our relationship with the biosphere we have perhaps made a Faustian bargain. In return for unrestrained use of the Earth's resources, we may have mortgaged a long-term future. Currently we are hoping to renegotiate the bargain, but there is detail in the small-print-clauses about climate change, destruction of ecosystems and consequent release of nutrients to waterways that we have ignored. Natural biomes determine that the biosphere is maintained in a state favourable to our particular biochemistry. Part of the mechanism is regulation of atmospheric gas composition through storage of carbon as biological deposits.

2. Shallow lakes and wetlands, and the tundras and forests of wet soil, store carbon at a much greater rate than the global ocean. The influence, on shallow lake systems, of warming coupled with degrees of eutrophication has been studied in replicated experimental ponds. The first experiment used modest nutrient addition and a

3 °C rise in temperature. Such warming led to some increase in phosphorus availability, takeover by an introduced warm-water species, Lagarosiphon major of the submerged plant community, and an increase in the frequency of severe deoxygenation, with occasional fish kills. 3. The second experiment used a rise of 4 °C against a similar ambient background to that of the first experiment, but a nutrient environment much closer to that of lowland eutrophicated waters. Especially with moderate nitrogen loading, floating duckweeds became very abundant, though submerged plants persisted. Oxygen concentrations fell markedly. Final fish biomass fell by 60% on warming and 80% at the highest nutrient loading used, but the combination of warming and even modest nutrients brought oxygen frequently to zero overnight and killed all the fish. Because the fish used (Gasterosteus aculeatus) were extremely resilient, there are severe implications for many other European fish species.

4. Analysis of oxygen curves allowed calculation of metabolic parameters of the tank systems. Both warming and nutrient addition substantially increased community respiration compared with photosynthesis. Extrapolation suggests that if this phenomenon is widespread, an increase of about 1.8 Gt over the 1990?s net annual atmospheric accumulation rate of 3.2 Gt might result. Since the IPCC models of future climate change do not include such biological feedbacks, they may thus seriously underestimate the future rise in temperature and its consequences.

5. Thematic implications: we do not know if our Faustian bargain can be renegotiated; our political and social institutions are poorly equipped in knowledge and barely accept the importance of biosphere processes, and our scientific establishment is reductionist and conforms to the values of the rest of society. Current approaches to mitigation of climate change attend only to carbon release from human institutions, with little or no reference to natural systems. The future is exceptionally uncertain.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02381.x

Munns Jr., Wayne R. "Assessing Risks to Wildlife Populations from Multiple Stressors: Overview of the Problem and Research Needs."** ***Ecology and Society **11.1 (2006): 23.**

Abstract

Wildlife populations are experiencing increasing pressure from human-induced changes in the landscape. Stressors including agricultural and urban land use, introduced invasive and exotic species, nutrient enrichment, direct human disturbance, and toxic chemicals directly or indirectly influence the quality and quantity of habitat used by terrestrial and aquatic wildlife. Governmental agencies such as the U.S. Environmental Protection Agency are required to assess risks to wildlife populations, in its broadest definition, that result from exposure to these stressors, yet considerable uncertainty exists with respect to how such assessments should be conducted. This uncertainty is compounded by questions concerning the interactive effects of co-occurring stressors, appropriate spatial scales of analysis, extrapolation of response data among species and from organisms to populations, and

imperfect knowledge and use of limited data sets. Further, different risk problems require varying degrees of sophistication, methodological refinement, and data quality. These issues suggest a number of research needs to improve methods for wildlife risk assessments, including continued development of population dynamics models to evaluate the effects of multiple stressors at varying spatial scales, methods for extrapolating across endpoints and species with reasonable confidence, stressor-response relations and methods for combining them in predictive and diagnostic assessments, and accessible data sets describing the ecology of terrestrial and aquatic species. Case study application of models and methods for assessing wildlife risk will help to demonstrate their strengths and limitations for solving particular risk problems.

Link

http://www.ecologyandsociety.org/vol11/iss1/art23/

Nielsen, D. L., et al. "Effects of Increasing Salinity on Freshwater Ecosystems in Australia." ***Australian Journal of Botany*** **51.6 (2003): 655.**

Abstract

Salt is a natural component of the Australian landscape to which a number of biota inhabiting rivers and wetlands are adapted. Under natural flow conditions periods of low flow have resulted in the concentration of salts in wetlands and riverine pools. The organisms of these systems survive these salinities by tolerance or avoidance. Freshwater ecosystems in Australia are now becoming increasingly threatened by salinity because of rising saline groundwater and modification of the water regime reducing the frequency of high-flow (flushing) events, resulting in an accumulation of salt. Available data suggest that aquatic biota will be adversely affected as salinity exceeds 1000 mg L^{-1} (1500 EC) but there is limited information on how increasing salinity will affect the various life stages of the biota. Salinisation can lead to changes in the physical environment that will affect ecosystem processes. However, we know little about how salinity interacts with the way nutrients and carbon are processed within an ecosystem. This paper updates the knowledge base on how salinity affects the physical and biotic components of aquatic ecosystems and explores the needs for information on how structure and function of aquatic ecosystems change with increasing salinity.

Link

http://www.publish.csiro.au/?paper=BT02115

Niemi, Gerald J., et al. "Overview of Case Studies on Recovery of Aquatic Systems from Disturbance." ***Environmental management*** **14.5 (1990): 571 - 587.**

Abstract

An extensive review of the published literature identified more than 150 case studies in which some aspect of resilience in freshwater systems was reported. Approximately 79% of

systems studied were lotic and the remainder lentic. Most of the stressor types were chemical with DDT (N=29) and rotenone (N=15) the most common. The most common nonchemical stressors were logging activity (N=16), flooding (N=8), dredging (N=3), and drought (N=7). The variety of endpoints to which recovery could be measured ranged from sparse data for phytoplankton (N=13), periphyton (N=6), and macrophytes (N=8) to relatively more data for fish (N=412) and macroinvertebrates (N=698). Unfortunately the same characteristics were rarely measured consistently among sites. For example, with respect to fish, more than 30 different species were studied and recovery was measured in many ways, most commonly on the basis of: (1) first reappearance of the species, (2) return time of predisturbance densities, and (3) return time of predisturbance average individual size. Based on these criteria, all systems in these studies seem to be resilient to most disturbances with most recovery times being less than three years. Exceptions included when (1) the disturbance resulted in physical alteration of the existing habitat, (2) residual pollutants remained in the system, or (3) the system was isolated and recolonization was suppressed.

Link

http://dx.doi.org/10.1007/bf02394710

***Norris, R., et al. "Multiple Lines and Levels of Evidence for Detecting Ecological Responses to Management Intervention. "** *In I.D. Rutherfurd, I. Wiszniewski, M.J. Askey-Doran and R. Glazik (Eds), Proceedings of the 4th Australian Stream Management Conference: linking rivers to landscapes, (pp. 456-463). Department of Primary Industries, Water and Environment, Hobart, Tasmania* **(2005)**

Abstract

Every year, millions of dollars are spent on river management and rehabilitation activities across Australia. Most of; these activities are based on assumptions about the ecology of river systems and potential threats or causes of degradation. While river management activities are widespread, monitoring and evaluation to assess if interventions have the anticipated ecological outcomes are far less common, particularly within an adaptive management framework. Rivers are usually subject to multiple stressors and we are often interested in establishing causal relationships between stressors, management interventions and environmental condition to ensure that: management actions are targeted, appropriate and are likely to achieve the stated objectives. Evaluating the: ecological response of rivers to management interventions can be complex. limited opportunities for replication and randomization often makes the more common impact assessment methods (e.g. BACI designs) difficult to apply, thereby reducing our ability to draw inferences on causality. A Multiple Levels and Lines of Evidence (MLLE) schema is presented from which it is possible to examine evidence for causality between environmental stressors, management Interventions and ecological outcomes. MLLE was originally developed for epidemiological studies when it was difficult to assign causality. Here we apply the MLLE schema to the design of monitoring programs for assessing the ecological outcomes of environmental flow

releases. The method complements the approaches adopted by various jurisdictions such as the IMEF process in NSW and the Australian Water Quality Monitoring Guidelines.

Link

http://adsabs.harvard.edu/abs/2005AGUSMNB44B..02N

Full record not available

***Norris, Richard, et al. *Causal Criteria Analysis Methods Manual: A Systematic Approach to Evaluate Causality in Environmental Science*. Canberra: eWater Cooperative Research Centre, 2008.**

Abstract

Scientists and managers are commonly faced with a situation where information from various sources provides conflicting results or advice. Therefore, it is important to have a transparent, consistent and logical framework to evaluate evidence and provide confidence in the conclusion drawn from that evidence. This manual describes how 'causal criteria' (sensu Hill 1965, Susser 1977, Downes et al. 2002) can be used to address questions of causality between environmental stressors, management interventions and ecological outcomes (Norris et al. 2005). More generally, the causal criteria approach is applicable to any scientific literature that aims to demonstrate a relationship between an apparent cause and an apparent effect. The causal criteria approach was originally developed for studies in epidemiology (medical science), where a lack of experimental data can result in a weak ability to draw inferences about causality (Hill 1965, Susser, 1991). However, a number of pieces of weak evidence may collectively build a sufficiently strong case to infer causality. The causal criteria approach provides a framework whereby the different pieces of evidence can be assimilated. The criteria were assembled in their modern form in a landmark 1964 report prepared by an advisory committee to the US Surgeon General on the health effects of smoking (USDHEW 1964). Like epidemiology, many ecological, hydrological, or other environmental studies also have limited opportunity for proper replication and randomization of treatments and observations. This weakens our ability to draw strong inferences. Over the last decade there has been a growing interest in applying the principles of causal criteria analysis to ecological questions. The causal criteria approach for ecological applications has been variously referred to as 'levels of evidence' (Downes, Barmuta, Fairweather et al., 2002) and 'multiple lines and levels of evidence' (Norris et al. 2005). The following causal criteria have largely been adapted from Downes et al. (2002) because of their relevance to ecological investigations.

Link

http://ecology.lamsinternational.com/moodle/login/index.php

***Ormerod, S. J., et al. "Multiple Stressors in Freshwater Ecosystems." *Freshwater Biology* 55 (2010): 1-4.**

Abstract

1. The fundamental importance of freshwater resources, the rapid extinction rate among freshwater species and the pronounced sensitivity of freshwater ecosystems to climate change together signal a pre-eminent need for renewed scientific focus and greater resources. Against this background, the Freshwater Biological Association in 2008 launched a new series of 'summit' Conferences in Aquatic Biology intended to develop and showcase the application of ecological science to major issues in freshwater management.

2. This collection of studies arose from the first summit entitled 'Multiple Stressors in Freshwater Ecosystems'. Although freshwater science and management are replete with multiple-stressor problems, few studies have been designed explicitly to untangle their effects.

3. The individual case studies that follow reveal the wide array of freshwaters affected by multiple stressors, the spatial and temporal scales involved, the species and ecosystem processes affected, the complex interactions between ecology and socioeconomics that engender such effects, the approaches advocated to address the problems and the challenges of restoring affected systems. The studies also illustrate the extent to which new challenges are emerging (e.g. through climate change), but also they develop a vision of how freshwaters might be managed sustainably to offset multiple stressors in future.

4. More generically, these case studies illustrate (i) how freshwaters might be at particular risk of multiple-stressor effects because of conflicts in water use, and because the hydrological cycle vectors stressor effects so effectively and so extensively; (ii) that dramatic, nonlinear, "ecological surprises" sometimes emerge as multiple-stressor effects develop and (iii) that good ecology and good ecologists add considerable value to other freshwater disciplines in understanding multiple stressors and managing their effects.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02395.x

Paine, Robert T., Mia J. Tegner, and Edward A. Johnson. "Compounded Perturbations Yield Ecological Surprises." ***Ecosystems*** **1.6 (1998): 535 - 545.**

Abstract

All species have evolved in the presence of disturbance, and thus are in a sense matched to the recurrence pattern of the perturbations. Consequently, disturbances within the typical range, even at the extreme of that range as defined by large, infrequent disturbances (LIDs), usually result in little long-term change to the system's fundamental character. We argue that more serious ecological consequences result from compounded perturbations within the normative recovery time of the community in question. We consider both physically based disturbance (for example, storm, volcanic eruption, and forest fire) and biologically based disturbance of populations, such as overharvesting, invasion, and disease, and their interactions. Dispersal capability and measures of generation time or age to first

reproduction of the species of interest seem to be the important metrics for scaling the size and frequency of disturbances among different types of ecosystems. We develop six scenarios that describe communities that have been subjected to multiple perturbations, either simultaneously or at a rate faster than the rate of recovery, and appear to have entered new domains or "ecological surprises." In some cases, three or more disturbances seem to have been required to initiate the changed state. We argue that in a world of ever-more-pervasive anthropogenic impacts on natural communities coupled with the increasing certainty of global change, compounded perturbations and ecological surprises will become more common. Understanding these ecological synergisms will be basic to environmental management decisions of the 21st century.

Link

http://www.springerlink.com/content/k3p2mvlvbkcjnfe9/

***Palmer, Margaret A., Holly L. Menninger, and Emily Bernhardt. "River Restoration, Habitat Heterogeneity and Biodiversity: A Failure of Theory or Practice?" *Freshwater Biology* 55 (2010): 205-22.**

Abstract

1. Stream ecosystems are increasingly impacted by multiple stressors that lead to a loss of sensitive species and an overall reduction in diversity. A dominant paradigm in ecological restoration is that increasing habitat heterogeneity (HH) promotes restoration of biodiversity. This paradigm is reflected in stream restoration projects through the common practice of re-configuring channels to add meanders and adding physical structures such as boulders and artificial riffles to restore biodiversity by enhancing structural heterogeneity.

2. To evaluate the validity of this paradigm, we completed an extensive evaluation of published studies that have quantitatively examined the reach-scale response of invertebrate species richness to restoration actions that increased channel complexity/HH. We also evaluated studies that used manipulative or correlative approaches to test for a relationship between physical heterogeneity and invertebrate diversity in streams that were not in need of restoration.

3. We found habitat and macroinvertebrate data for 78 independent stream or river restoration projects described by 18 different author groups in which invertebrate taxa richness data in response to the restoration treatment were available. Most projects were successful in enhancing physical HH; however, only two showed statistically significant increases in biodiversity rendering them more similar to reference reaches or sites.

4. Studies manipulating structural complexity in otherwise healthy streams were generally small in scale and less than half showed a significant positive relationship with invertebrate diversity. Only one-third of the studies that attempted to correlate biodiversity to existing levels of in-stream heterogeneity found a positive relationship.

5. Across all the studies we evaluated, there is no evidence that HH was the primary factor controlling stream invertebrate diversity, particularly in a restoration context. The findings indicate that physical heterogeneity should not be the driving force in selecting restoration approaches for most degraded waterways. Evidence suggests that much more must be done to restore streams impacted by multiple stressors than simply re-configuring channels and enhancing structural complexity with meanders, boulders, wood, or other structures.

6. Thematic implications: as integrators of all activities on the land, streams are sensitive to a host of stressors including impacts from urbanisation, agriculture, deforestation, invasive species, flow regulation, water extractions and mining. The impacts of these individually or in combination typically lead to a decrease in biodiversity because of reduced water quality, biologically unsuitable flow regimes, dispersal barriers, altered inputs of organic matter or sunlight, degraded habitat, etc. Despite the complexity of these stressors, a large number of stream restoration projects focus primarily on physical channel characteristics. We show that this is not a wise investment if ecological recovery is the goal. Managers should critically diagnose the stressors impacting an impaired stream and invest resources first in repairing those problems most likely to limit restoration.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02372.x

Pringle, Catherine M., Mary C. Freeman, and Byron J. Freeman. "Regional Effects of Hydrologic Alterations on Riverine Macrobiota in the New World: Tropical–Temperate Comparisons." ***Bioscience*** **50.9 (2000): 807.**

Abstract

Modifications of lower watersheds such as water abstraction, channel modification, land-use changes, nutrient enrichment, and toxic discharge can set off a cascade of events upstream that are often overlooked. This oversight is of particular concern since most rivers are altered by humans in their lower drainages and most published ecological investigations of lotic systems have focused on headwater streams. Factors contributing to ecological processes or biophysical legacies in upper watersheds often go unacknowledged because they occur at disparate geographic locations downstream (e.g., gravel mining, water abstraction, dams) with significant lag times. This paper considers examples of how alterations to streams and rivers in their lower reaches can produce biophysical legacies in upstream reaches on levels from genes to ecosystems. Examples include: 1) genetic- and species-level changes, such as reduced genetic flow and variation in isolated upstream populations; 2) population- and community-level changes that occur when degraded downstream areas act as population "sinks" for "source" populations of native species upstream or, conversely, as "source" populations of exotic species that migrate upstream; and 3) ecosystem- and landscape-level changes (e.g., nutrient cycling, primary productivity, regional patterns of biodiversity) that can occur in headwater systems as a result of downstream habitat deterioration and hydrologic modifications. Finally, a case study from my own research illustrates the importance of careful consideration of downstream-upstream linkages in formulating research questions, designing experiments, making predictions, and interpreting results. The

effects of dams and associated water abstraction in lowland streams of Puerto Rico has forced my colleagues and me to re-evaluate the results of ecological research that we have conducted in highland streams over the past decade and to redirect our research to consider downstream-upstream linkages.

Link

http://academic.research.microsoft.com/Paper/11819009.aspx

Pringle, Catherine M. "Exploring how Disturbance is Transmitted Upstream: Going Against the Flow." ***Journal of the North American Benthological Society*** **16.2, New Concepts in Stream Ecology: Proceedings of a Symposium (1997): pp. 425-438.**

Abstract

Because there are many long-established dams in temperate zones, paradigms and theories of how hydrologic modifications caused by dams alter the ecological dynamics of rivers are based largely on studies of temperate basins (e.g., Poff et al. 1997). Little is known about biotic responses to hydrologic modifications in tropical streams; generalizations about the effects of dams in the tropics are constrained by limited data on recently constructed, and relatively few, dams. Moreover, general ecological understanding of the effects of dams in both tropical and temperate zones is constrained by a lack of baseline information on the distribution and ecology of aquatic biota before dam construction, as well as by an overemphasis on economically important species. This article has two main objectives: to examine what is known about regional effects of hydrologic modifications in temperate and tropical areas of the New World (i.e., North and South America and the Caribbean), with an emphasis on fishes and molluscs; and to discuss research needs regarding regional effects of hydrologic alterations in temperate and tropical regions. A better understanding of regional effects of cumulative hydrologic alterations could help inform decisions on the nature and location of future hydrologic modifications. We begin with a brief description of the scope of hydrologic alterations in the New World, emphasizing dams. This is followed by a summary of biotic patterns that have emerged in hydrologically altered rivers draining temperate regions. We use the highly regulated Mobile River basin in southeastern North America as a temperate-zone case study to discuss specific biological effects. We then focus on the vulnerability of the biota of neotropical rivers and discuss biotic patterns that are emerging in response to relatively recent hydrologic modifications. The Plata River Basin of South America provides a tropical case study. (The term *tropical* is used to refer to the equatorial area [approximately 30° north and south of the equator] between the northern and southern subtropical dryland zones.) We end by examining research needs and gaps in our understanding of the ecological effects of hydrologic modifications on landscape and regional scales in the New World.

Link

http://www.jstor.org/stable/1468028

Quinlan, Roberto, et al. "Long-Term Assessments of Ecological Effects of Anthropogenic Stressors on Aquatic Ecosystems from Paleoecological Analyses: Challenges to Perspectives of Lake Management." *Canadian Journal of Fisheries and Aquatic Sciences* **65.5 (2008): 933-44.**

Abstract

Paleolimnological techniques are important for determining background ecological conditions and ecosystem responses to stressors when long-term data sets are absent. Research at the Dorset Environmental Sciences Centre (Ontario, Canada) has included paleolimnological studies to determine the effects of anthropogenic stressors on shield lakes, including eutrophication, acidic deposition, and climate change. Diatom-based total phosphorus (TP) inferences suggest that [TP] has declined in some lakes, despite increased inputs from anthropogenic sources. When coupled with siliceous algae-based pH inferences that suggest landscape-scale long-term acidification, these results indicate that the ecological effects of anthropogenic P inputs are being masked by the cumulative effects of multiple stressors. Detailed stratigraphic analyses of lakes that have experienced severe anthropogenic disturbances indicate that despite measured and inferred recovery in epilimnetic [TP] to predisturbance concentrations, pelagic communities have not recovered to predisturbance community composition; profundal communities and the variables associated with water quality (e.g., hypolimnetic oxygen) have also not recorded recovery. This suggests that (*i*) typical modeling approaches to quantify the effects of anthropogenic inputs on lake water [TP] should be used with caution and (*ii*) lake management approaches that follow the paradigm of "water quality recovery = biological recovery" may not be applicable to ecosystems being affected by multiple anthropogenic stressors.

Link

http://rparticle.web-p.cisti.nrc.ca/rparticle/AbstractTemplateServlet?calyLang=eng&journal=cjfas&volume=65&year=2008&issue=5&msno=f08-027

Richards, C., L. B. Johnson, and G. E. Host. "Landscape-Scale Influences on Stream Habitats and Biota." *Canadian Journal of Fisheries and Aquatic Sciences* **53.S1 (1996): 295 - 311.**

Abstract

The relative influence of geologic versus anthropogenic attributes of catchments on stream ecosystems was examined in 45 catchments of a river basin in central Michigan. Each catchment was characterized by land use, surficial geology, elevation, and hydrography, and summaries of these data were related to physical habitat characteristics that had the greatest influence on macroinvertebrate assemblages. Partial redundancy analysis revealed that geologic and land-use variables had similar magnitudes of influence on stream habitats. Of the geologic variables, catchment area, proportion of acustrine clays, and glacial outwash materials had the strongest influence on physical habitat, particularly on channel dimensions. Row-crop agriculture and the presence of wetlands were the most important land-use

variables, particularly influencing amounts of woody debris. Stream buffers (100 m) were more important than whole catchment data for predicting sediment-related habitat variables; however, channel morphology was more strongly related to whole catchments. Results suggest that catchment-wide geology and land-use characteristics may be more important than stream buffers for maintaining or restoring stream ecosystems. These techniques can be used to develop biologic signatures of catchment condition that discriminate causal factors influencing the biodiversity and health of stream ecosystems.

Link

http://rparticle.web-p.cisti.nrc.ca/rparticle/AbstractTemplateServlet?journal=cjfas&volume=53&year=1996&issue=53&msno=f96-006&calyLang=eng

Roni, Phil, Karrie Hanson, and Tim Beechie. "Global Review of the Physical and Biological Effectiveness of Stream Habitat Rehabilitation Techniques." *North American Journal of Fisheries Management* **28.3 (2008): 856 - 890.**

Abstract

The degradation of inland aquatic habitats caused by decades of human activities has led to worldwide efforts to rehabilitate freshwater habitats for fisheries and aquatic resources. We reviewed published evaluations of stream rehabilitation techniques from throughout the world, including studies on road improvement, riparian rehabilitation, floodplain connectivity and rehabilitation, instream habitat improvement, nutrient addition, and other, less-common techniques. We summarize current knowledge about the effectiveness of these techniques for improving physical habitat and water quality and increasing fish and biotic production. Despite locating 345 studies on effectiveness of stream rehabilitation, firm conclusions about many specific techniques were difficult to make because of the limited information provided on physical habitat, water quality, and biota and because of the short duration and limited scope of most published evaluations. Reconnection of isolated habitats, floodplain rehabilitation, and instream habitat improvement have, however, proven effective for improving habitat and increasing local fish abundance under many circumstances. Techniques such as riparian rehabilitation, road improvements (sediment reduction), dam removal, and restoration of natural flood regimes have shown promise for restoring natural processes that create and maintain habitats, but no long-term studies documenting their success have yet been published. Our review demonstrates that the failure of many rehabilitation projects to achieve objectives is attributable to inadequate assessment of historic conditions and factors limiting biotic production; poor understanding of watershed-scale processes that influence localized projects; and monitoring at inappropriate spatial and temporal scales. We suggest an interim approach to sequencing rehabilitation projects that partially addresses these needs through protecting high-quality habitats and restoring connectivity and watershed processes before implementing instream habitat improvement projects.

Link

http://afsjournals.org/doi/abs/10.1577/M06-169.1

Roth, Nancy E., J. David Allan, and Donna L. Erickson. "Landscape Influences on Stream Biotic Integrity Assessed at Multiple Spatial Scales." ***Landscape Ecology*** **11.3 (1996): 141 - 156.**

Abstract

The biological integrity of stream ecosystems depends critically on human activities that affect land use/cover along stream margins and possibly throughout the catchment. We evaluated stream condition using an Index of Biotic Integrity (IBI) and a habitat index (HI), and compared these measures to landscape and riparian conditions assessed at different spatial scales in a largely agricultural Midwestern watershed. Our goal was to determine whether land use/cover was an effective predictor of stream integrity, and if so, at what spatial scale. Twenty-three sites in first-through third-order headwater streams were surveyed by electrofishing and site IBIs were calculated based on ten metrics of the fish collection. Habitat features were characterized through field observation, and site HIs calculated from nine instream and bank metrics. Field surveys, aerial photograph interpretation, and geographic information system (GIS) analyses provided assessments of forested land and other vegetation covers at the local, reach, and regional (catchment) scales. The range of conditions among the 23 sites varied from poor to very good based on IBI and HI scores, and habitat and fish assemblage measures were highly correlated. Stream biotic integrity and habitat quality were negatively correlated with the extent of agriculture and positively correlated with extent of wetlands and forest. Correlations were strongest at the catchment scale (IBI with % area as agriculture, r^2=0.50, HI with agriculture, r^2=0.76), and tended to become weak and non-significant at local scales. Local riparian vegetation was a weak secondary predictor of stream integrity. In this watershed, regional land use is the primary determinant of stream conditions, able to overwhelm the ability of local site vegetation to support high-quality habitat and biotic communities.

Link
http://dx.doi.org/10.1007/bf02447513

Said, A., et al. "Exploring an Innovative Watershed Management Approach: From Feasibility to Sustainability."** ***Energy **31.13 (2006): 2373 - 2386.**

Abstract

Watershed management is dedicated to solving watershed problems on a sustainable basis. Managing watershed development on a sustainable basis usually entails a balance between the needs of humans and nature, both in the present and in the future. From a watershed or water resources development basis, these problems can be classified into five general categories: lack of water quantity, deterioration in water quality, ecological impacts, weak public participation, and weak economic value. The first three categories can be combined to make up physical sustainability while the last two categories can be defined as social and economic sustainability. Therefore, integrated watershed management should be designed to achieve physical sustainability utilizing, to the greatest extent possible, public participation in

an economically viable manner. This study demonstrates an innovative approach using scientific, social, and motivational feasibilities that can be used to improve watershed management. Scientific feasibility is tied to the nature of environmental problems and the scientific means to solve them. Social feasibility is associated with public participation. Motivational feasibility is related to economic stimulation for the stakeholders to take actions. The ecological impacts, lack of water quantity and deterioration in water quality are problems that need scientific means in order to improve watershed health. However, the implementation of these means is typically not achievable without the right public participation. In addition, public participation is typically accelerated by economic motivation for the stakeholders to use the resources in a manner that improves watershed health. The Big Lost River in south-central Idaho has been used as an illustration for implementing scientific, social and motivational feasibilities and in a manner that can achieve sustainability relative to water resources management. However, the same approach can be used elsewhere after appropriate modifications.

Link

http://dx.doi.org/10.1016/j.energy.2006.02.002

Schindler, D. W. "The Cumulative Effects of Climate Warming and Other Human Stresses on Canadian Freshwaters in the New Millennium." ***Canadian Journal of Fisheries and Aquatic Sciences*** **58.1 (2001): 18-29.**

Abstract

Climate warming will adversely affect Canadian water quality and water quantity. The magnitude and timing of river flows and lake levels and water renewal times will change. In many regions, wetlands will disappear and water tables will decline. Habitats for cold stenothermic organisms will be reduced in small lakes. Warmer temperatures will affect fish migrations in some regions. Climate will interact with overexploitation, dams and diversions, habitat destruction, non-native species, and pollution to destroy native freshwater fisheries. Acute water problems in the United States and other parts of the world will threaten Canadian water security. Aquatic communities will be restructured as the result of changes to competition, changing life cycles of many organisms, and the invasions of many non-native species. Decreased water renewal will increase eutrophication and enhance many biogeochemical processes. In poorly buffered lakes and streams, climate warming will exacerbate the effects of acid precipitation. Decreases in dissolved organic carbon caused by climate warming and acidification will cause increased penetration of ultraviolet radiation in freshwaters. Increasing industrial agriculture and human populations will require more sophisticated and costly water and sewage treatment. Increased research and a national water strategy offer the only hope for preventing a freshwater crisis in Canada.

Link

http://rparticle.web-p.cisti.nrc.ca/rparticle/AbstractTemplateServlet?calyLang=eng&journal=cjfas&volume=58&year=2001&issue=1&msno=f00-179

Schindler, David W., and John P. Smol. "Cumulative Effects of Climate Warming and Other Human Activities on Freshwaters of Arctic and Subarctic North America." ***A Journal of the Human Environment*** **35.4 (2006): 160-8.**

Abstract

Despite their generally isolated geographic locations, the freshwaters of the north are subjected to a wide spectrum of environmental stressors. High-latitude regions are especially sensitive to the effects of recent climatic warming, which have already resulted in marked regime shifts in the biological communities of many Arctic lakes and ponds. Important drivers of these limnological changes have included changes in the amount and duration of snow and ice cover, and, for rivers and lakes in their deltas, the frequency and extent of spring floods. Other important climate-related shifts include alterations in evaporation and precipitation ratios, marked changes in the quality and quantity of lake and river water inflows due to accelerated glacier and permafrost melting, and declining percentages of precipitation that falls as snow. The depletion of stratospheric ozone over the north, together with the clarity of many Arctic lakes, renders them especially susceptible to damage from ultraviolet radiation. In addition, the long-range atmospheric transport of pollutants, coupled with the focusing effects of contaminant transport from biological vectors to some local ecosystems (e.g., salmon nursery lakes, ponds draining seabird colonies) and biomagnification in long food chains, have led to elevated concentrations of many persistent organic pollutants (e.g., insecticides, which have never been used in Arctic regions) and other pollutants (e.g., mercury). Rapid development of gas and oil pipelines, mining for diamonds and metals, increases in human populations, and the development of all-season roads, seaports, and hydroelectric dams will stress northern aquatic ecosystems. The cumulative effects of these stresses will be far more serious than those caused by changing climate alone.

Link

http://www.bioone.org/doi/full/10.1579/0044-7447(2006)35[160:CEOCWA]

Schindler, D. W., et al. "Consequences of Climate Warming and Lake Acidification for UV-B Penetration in North American Boreal Lakes." ***Nature*** **379.6567 (1996): 705-8.**

Abstract

Recent ecological work on aquatic populations, communities, and ecosystems is reviewed for advances which show promise as early indicators of anthropogenic stress in aquatic ecosystems. Work at the Experimental Lakes Area (ELA) in northwestern Ontario indicates that among the earliest of responses to stress are changes in species composition of small, rapidly-reproducing species with wide dispersal powers such as phytoplankton, and the disappearance of sensitive organisms from aquatic communities. Work elsewhere illustrates that the incidence of morphological abnormalities in benthic invertebrates is also highly sensitive to pollution stress. For several categories of pollutants, this sensitivity of benthic organisms may be due to the greater concentrations of pollutants in sediments than in the water column. Variables reflecting ecosystem functions such as primary production, nutrient

cycling, and respiration, were not altered by eutrophication, acidification, or cadmium addition at ELA, and are relatively poor indicators of early stress. Species diversity of phytoplankton was also insensitive to low levels of stress. Mesocosm experiments appear to be fruitful for addressing chemical- or plankton-related problems, but are less useful for addressing community- or ecosystem-level questions. Among population-level approaches, life-table population studies of invertebrates appear to be the most sensitive early indicators of stress on ecosystems. Relative sensitivities of freshwater and forested terrestrial ecosystems exposed to airborne pollutants are compared. Primary production seems to be reduced at a much earlier stage of air pollution stress in terrestrial ecosystems than in aquatic systems. Soils, like lake sediments, tend to be sinks for pollutants. This may protect the pelagic regions of lakes from influxes of toxins that would occur if watersheds and sediments were unreactive, but cause additional stresses to the fauna and flora of soils and sediments. In extreme cases, high concentrations of toxins may inhibit the replacement of terrestrial producers. The importance of long-term monitoring in distinguishing natural from anthropogenic stress is discussed. It is suggested that paleoecological techniques be rapidly developed and calibrated with whole-ecosystem experiments to resolve certain inadequacies of past monitoring records

Link

http://www.nature.com/nature/journal/v379/n6567/abs/379705a0.html

Schindler, D. W. "Detecting Ecosystem Responses to Anthropogenic Stress." *Canadian Journal of Fisheries and Aquatic Sciences* **44.S1 (1987): s6 - s25.**

Abstract

Climate warming, acid deposition and increasing exposure to ultraviolet radiation are all regarded as widespread problems in boreal ecosystems. Here we report observations from twenty years of whole-lake acidification experiments, which show that these three problems are intimately linked, In our study area in northwestern Ontario, both climate warming and lake acidification led to declines in the dissolved organic carbon content of lake waters, allowing increased penetration of solar radiation. We suggest that some of the changes in aquatic ecosystems that have been attributed to lake acidification may in fact have involved increased exposure to ultraviolet light. Moreover, it seems that-particularly in clear, shallow lakes and streams-climate warming and/or acidification can be more effective than stratospheric ozone depletion in increasing the exposure of aquatic organisms to biologically effective UV-B radiation.

Link

http://dx.doi.org/10.1139/f87-276

Smol, John P. "The Power of the Past: Using Sediments to Track the Effects of Multiple Stressors on Lake Ecosystems." *Freshwater Biology* **55 (2010): 43-59.**

Abstract

1. One of the greatest challenges faced by limnologists, as well as most ecologists and environmental scientists, is finding data with time scales appropriate to their questions. Because of the general lack of reliable long-term monitoring data, it is often difficult to determine the nature and timing of ecosystem changes. In lieu of direct monitoring data, palaeolimnologists have developed a variety of physical, chemical and biological approaches to track past changes in aquatic ecosystems using proxy data archived in lake and river sediments. This article summarizes a few of our recent palaeolimnological programs that have studied the effects of multiple stressors on lake ecosystems and demonstrates how palaeolimnological approaches can circumvent this common problem of data availability.

2. Lakewater calcium concentrations are declining in many softwater lake regions because logging and acid precipitation have lowered calcium levels in soils. In many cases, however, the onset of lakewater calcium decline predates direct observation, and so documenting the effects on freshwater ecosystems may be complex. By combining laboratory, field and palaeolimnological approaches, it is now evident that keystone taxa (e.g. Daphnia spp.) have been severely affected by these calcium declines.

3. Some of the most common complaints received by lake managers concern the smell and taste of water. Although the root causes of taste and odor problems vary, compounds released by certain species of algae are often responsible. In nutrient-poor or mesotrophic lakes, colonial chrysophytes are often the culprits, including scaled taxa of the genus Synura. Palaeolimnological approaches can be used to assess the various multiple stressors that influence the abundance of these phytoplankton.

4. Thematic implications: recent climatic warming is affecting a wide range of lake ecosystems in diverse and often complex ways across vast geographical regions, and this has added to the complexities of limnological responses to other stressors. As more palaeolimnological studies are completed, meta-analyses of sedimentary profiles can now be used to help disentangle the effects of climate warming from other environmental variables to determine how various components of lake ecosystems are responding to these multiple stressors.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02373.x

Statzner, B., And F. Sperling. "Potential Contribution of System-Specific Knowledge (SSK) to Stream-Management Decisions: Ecological and Economic Aspects."** ***Freshwater Biology **29.2 (1993): 313-42.**

Abstract

1. Stream-management decisions must produce an optimal cost-effect ratio, as related to social, ecological and economic concerns. Therefore, decisions must be reached in a systematic approach by scrutinizing the system-specific knowledge (SSK) provided by many disciplines.

2. This paper is organized into five sections: following the introduction (Section 1), Section 2 sets a framework for the numerous elements of the SSK that can serve as a checklist to identify potentially important topics for a particular management decision; Section 3 illustrates errors in stream-management policies that have been made because the SSK was not considered; Section 4 demonstrates how the SSK can be applied in formulating appropriate stream- and water-management policies; finally Section 5 summarizes the major points in the context of alternative stream-management strategies.

3. Examples on limiting values in Europe, restrictions of NH4-N emission, and the routine application of the Saprobian index demonstrate that current management practices often ignore the SSK.

4. Combining trivial elements of the SSK we demonstrate how complex problems of stream management can be solved, focusing on the sources, sinks, and effects of water, organic carbon, nitrogen and phosphorus.

5. On the basis of costs and effects, we rate various management options for a fictitious north German lowland catchment. If that catchment does not carry a dense human population, SSK-based management is distinctly more efficient than traditional management, which focuses on a minor sink (sewer system plus sewage treatment plant).

6. Stream management ignoring the SSK wastes financial, intellectual, and natural resources. If we project the estimated costs for water-resource management in Germany over the forthcoming decade on to the standards of recent European Community (EC) guidelines concerning this subject, a large portion of a sum of around $US 1-2 trillion (1012) will be squandered in the EC unless practices change.

7. The results of our analysis are rather disturbing and suggest that totally different practices are needed in legislation, administration and execution, monitoring, and research. Therefore, we propose that our paper be the starting point for a discussion involving representatives of all relevant disciplines about potential priorities for new management strategies.

Link

http://dx.doi.org/10.1111/j.1365-2427.1993.tb00767.x

***Statzner, Bernhard, And Leah A. Bêche. "Can Biological Invertebrate Traits Resolve Effects of Multiple Stressors on Running Water Ecosystems?"** *Freshwater Biology* **55 (2010): 80-119.**

Abstract

1. Accurately assessing the effects of multiple human-caused stressors on freshwater (and other) ecosystems is an essential step in the development of efficient decision support tools for environmental managers. Our objective is to review potentials and limitations of the use of biological traits as indicators (BTIs) of multiple stressor effects on running water (i.e. lotic) ecosystems.

2. Pioneers in ecology provided mechanistic explanations for responses of alternative biological traits to a given stressor and for the action of habitat harshness as a trait filter. These ideas were subsequently integrated in theoretical ecological constructs (e.g. Habitat Templet Concept) that form the basis of the BTI approach.

3. To resolve the effects of multiple stressors on running waters requires multiple traits of a biologically diverse group of organisms such as lotic invertebrates. To meet this goal, however, recently created databases on the biological traits of lotic invertebrates must be expanded and unified.

4. Addressing the technical implementation of the BTI approach, we illustrate that anticipated problems with phylogenetic trait syndromes are seemingly less serious in reality and that presence?absence data of genera and few sample replicates are sufficient for accurate trait descriptions of invertebrate communities.

5. Current trends in politics demand that biomonitoring tools be effective at large scales, i.e. large-scale trait patterns of natural communities (i.e. at reference conditions) should be relatively stable. The trait composition of natural invertebrate communities is relatively stable at the scale of Europe and North America because trait filters of natural lotic habitats act similarly across large biogeographical units.

6. The mechanistic actions of stressors on the biological traits of invertebrates should facilitate a priori predictions, but the complexity of potential trait responses makes such predictions sometimes difficult.

7. To illustrate potentials and limitations of BTIs to identify a given stressor acting exclusively (or primarily), we examine the (i) use of functional feeding groups to indicate the action of various stressors and (ii) trait responses to an indirectly acting stressor (discharge variation) and to a more directly acting stressor (near-bottom flow). If the excessive use of specific traits for the indication of too many different stressors is avoided and a given stressor acts directly on traits as a priori predicted, reliable interpretations of trait responses can be achieved.

8. To illustrate how BTIs can identify individual stressors acting in combination, we examine three cases of multiple stressors: (i) heavy metal pollution in combination with cargo-ship traffic; (ii) eutrophication and fine sediment deposits associated with land use; and (iii) various stressors associated with climate change in combination with salinity. If the number of the assessed traits is sufficiently great and the action of each individual among the multiple stressors is not too weak, multiple traits can potentially resolve the effects of multiple stressors.

9. Thematic implications: if the expansion and unification of existing trait databases can be achieved, the rapidly growing knowledge about biological trait responses of lotic invertebrates to individual and multiple stressors should enable the identification of management priorities focused on: (i) individually acting stressors (manage stressor A at site X prior to stressor B at site Y); (ii) multiple stressors acting in different combinations at different sites (manage stressors A & B at site X prior to stressors C & D at site Y); and (iii)

individual stressors acting in combination (manage stressor A prior to stressor B at site X). Thus, the BTI approach has the potential to inaugurate a new era in the biomonitoring of lotic (and other) ecosystems.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02369.x

Stein, Eric D., and Donald B. Cadien. "Ecosystem Response to Regulatory and Management Actions: The Southern California Experience in Long-Term Monitoring." 59 Vol. (2009).

Abstract

Billions of dollars have been invested over the past 35 years in reducing pollutant emissions to coastal environments. Evaluation of the effectiveness of this investment is hampered by the lack of long-term consistent data. A rare opportunity exists in southern California to evaluate the effectiveness of management actions by analyzing long-term monitoring of effluent, sediment, benthos, and fish and comparing this trend data to periodic regional surveys of environmental condition. In this paper, we ask the question "have improvements in effluent quality in response to environmental regulation translated into improvements in the receiving environment?" Results indicate that management actions directed at reducing mass emissions from wastewater treatment plants (POTWs) have resulted in substantial improvement in aquatic communities. However, the magnitude and timing of response varies by indicator suggesting that use of multiple assessment endpoints is necessary to adequately interpret trends. Reductions in the effect of POTW effluent have allowed managers to shift resources to address other contaminant sources such as stormwater and resuspension of legacy pollutants.

Link

http://sccwrp.org/Documents.aspx

***Stewart-Koster, B., et al. "The use of Bayesian Networks to Guide Investments in Flow and Catchment Restoration for Impaired River Ecosystems." *Freshwater Biology* 55.1 (2010): 243-60.**

Abstract

1.The provision of environmental flows and the removal of barriers to water flow are high priorities for restoration where changes to flow regimes have caused degradation of riverine ecosystems. Nevertheless, flow regulation is often accompanied by changes in catchment and riparian land-use, which also can have major impacts on river health via local habitat degradation or modification of stream energy regimes.

2.The challenges are determining the relative importance of flow, land-use and other impacts as well as deciding where to focus restoration effort. As a consequence, flow, catchment and

riparian restoration efforts are often addressed in isolation. River managers need decision support tools to assess which flow and catchment interventions are most likely to succeed and, importantly, which are cost-effective.

3. Bayesian networks (BNs) can be used as a decision support tool for considering the influence of multiple stressors on aquatic ecosystems and the relative benefits of various restoration options. We provide simple illustrative examples of how BNs can address specific river restoration goals and assist with the prioritization of flow and catchment restoration options. This includes the use of cost and utility functions to assist decision makers in their choice of potential management interventions.

4. A BN approach facilitates the development of conceptual models of likely cause and effect relationships between flow regime, land-use and river conditions and provides an interactive tool to explore the relative benefits of various restoration options. When combined with information on the costs and expected benefits of intervention, one can derive recommendations about the best restoration option to adopt given the network structure and the associated cost and utility functions.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02219.x

Stillwater Sciences. ***Lagunitas Limiting Factors Analysis: Liming Factors for Coho Salmon and Steelhead. Final Report.*** **2008.**

Abstract

The Marin Resource Conservation District, along with the Tomales Bay Watershed Council, Point Reyes National Seashore, Marin Municipal Watershed District (MMWD), Salmon Protection and Watershed Network (SPAWN), Trout Unlimited, and Marin County sponsored the Lagunitas Creek Watershed Limiting Factors Analysis as part of a Proposition 13, Coastal Nonpoint Source Control Program grant. The overall purpose of the grant is to fill information gaps related to physical and biological factors controlling salmonid population dynamics within the watershed. The project was completed in two phases. Because of the high level of public support and interest within the watershed, a number of studies and monitoring programs have been implemented in recent years. Much of the focus of Phase I work was to review and synthesize this existing information in order to develop hypotheses and identify information gaps concerning salmonid population dynamics. Phase II consisted of implementing focused field studies to fill key information gaps identified during Phase I and synthesizing the results of these studies with analyses that were based on existing information. This report combines the results from both phases of study. Two focal species were selected by Marin Resource Conservation District and the Lagunitas Advisory Group for consideration during the limiting factors analysis—coho salmon (Oncorhynchus kisutch) and steelhead (O. mykiss). Although other species/indicators were considered for inclusion in the analysis (freshwater bivalves, California freshwater shrimp, California red-legged frog, aquatic macroinvertebrates), it is believed that a wide variety of ecosystem attributes important to these species and the aquatic community as a whole would be

reasonably addressed by focusing on the needs of these two anadromous salmonid species throughout their freshwater life histories. Objectives There were four major objectives for the Lagunitas Creek watershed limiting factors analysis: 1. Develop conceptual models and test hypotheses about factors potentially limiting populations of the focal species using the available literature and data; 2. Refine conceptual models based on the Phase I analysis of available data; 3. Test conceptual models and hypotheses through focused field studies during Phase II; 4. Develop restoration recommendations based on the results of focused field studies and analysis of existing information. Approach Our approach to stream and salmonid restoration is based primarily on restoring or reinitiating geomorphic and ecological processes to achieve the goal of self-sustaining target populations. A key objective is to link land-use activities with their effects on salmonid populations. Human activities affect watershed inputs (e.g., water, sediment), leading to a cascade of changes in important geomorphic processes, habitat characteristics, species abundance, and population dynamics (Figure 1-1).

Link

http://www.stillwatersci.com/resources/2008lagunitasLFA.pdf

Stillwater Sciences. ***Linking Biological Responses to River Processes: Implications for Conservation and Management of the Sacramento River—a Focal Species Approach. Final Report.*** **2007.**

Abstract

This report (the "Linkages Report") is part of the Sacramento River Ecological Flows Study (the "Study") initiated by The Nature Conservancy (TNC) in collaboration with ESSA Technologies, Stillwater Sciences, UC Davis, and UC Berkeley. The study area focuses on the mainstem Sacramento River corridor between Keswick Dam (RM 302) and Colusa (RM 143), including the channel, adjacent floodplain and riparian habitats, and off-channel water bodies. The over arching goal of the Study is to define how flow characteristics (e.g., the magnitude, timing, duration, and frequency) and associated management actions (such as gravel augmentation and changes in bank armoring) influence the creation and maintenance of habitats for a number of native species that occur in the Sacramento River corridor. This Linkages Report is designed to provide resource managers and stakeholders with information and tools that will allow them to explore how changes in the pattern of flow releases can affect habitats in the Sacramento River. In this way, the Linkages Report should provide useful information for water operations planning, restoration planning, species recovery planning, and storage investigations (e.g., the Shasta Lake Water Resources and North-of-the-Delta Offstream Storage investigations) that focus on the Sacramento River. The information in this Linkages Report builds on the earlier review of Sacramento River ecological flow issues conducted by Kondolf et al. (2000) for CALFED.

Link

http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=5045

Strayer, David L. "Alien Species in Fresh Waters: Ecological Effects, Interactions with Other Stressors, and Prospects for the Future."** ***Freshwater Biology **55 (2010): 152-74.**

Abstract

1. Biological invasions are numerous in fresh waters around the world. At least hundreds of freshwater species have been moved outside of their native ranges by vectors such as ballast water, canals, deliberate introductions, and releases from aquaria, gardens, and bait buckets. As a result, many bodies of fresh water now contain dozens of alien species.

2. Invasions are highly nonrandom with respect to the taxonomic identity and biological traits of the invaders, the ecological characteristics of the ecosystems that are invaded, and the geographical location of the ecosystems that supply and receive the invaders.

3. Some invaders have had deep and pervasive effects on the ecosystems that they invade. Classes of ecologically important invaders in fresh waters include molluscs that are primary consumers and disrupt the food web from its base, fishes that disrupt the food web from its apex or centre, decapods that act as powerful omnivores, aquatic plants that have strong engineering effects and affect the quality and quantity of primary production, and diseases, which probably have been underestimated as an ecological force.

4. The number of alien species in freshwater ecosystems will increase in the future as new aliens are moved outside of their native ranges by humans, and as established aliens fill their potential ranges. Alien species create 'no-analogue' ecosystems that will be difficult to manage in the future. We may be able to reduce future impacts of invaders by making more serious efforts to prevent new invasions and manage existing invaders.

5. Thematic implications: interactions between alien species and other contemporary stressors of freshwater ecosystems are strong and varied. Because disturbance is generally thought to favour invasions, stressed ecosystems may be especially susceptible to invasions, as are highly artificial ecosystems. In turn, alien species can strongly alter the hydrology, biogeochemical cycling, and biotic composition of invaded ecosystems, and thus modulate the effects of other stressors. In general, interactions between alien species and other stressors are poorly studied

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02380.x

***Swanson, Stella M. "Multiple Stressors: Literature Review and Gap analysis - 00ECO2B."Web. 12/22/2010 <http://www.iwaponline.com/wio/2004/08/wio200408WF00ECO2B.htm>.**

Abstract

There is a pressing need for developing and testing a general set of theories in order to provide a confident basis for prediction of multiple stressor effects. Confident prediction is central to confident decision making in water pollution control. Consequently, WERF commissioned this study, which has as its goal to provide a study design based on good science that helps establish a general, conceptual approach to multiple stressors. The objectives addressed in this report are: (1) review and critique the existing body of knowledge for multiple stressors; (2) develop a searchable, annotated bibliography of multiple stressor research; and, (3) identify gaps in the body of knowledge.

Link

http://www.iwaponline.com/wio/2004/08/wio200408WF00ECO2B.htm

PDF secured

Tockner, Klement, et al. "Multiple Stressors in Coupled River-Floodplain Ecosystems."** ***Freshwater Biology **55 (2010): 135-51.**

Abstract

1. Riverine floodplains are highly complex, dynamic and diverse ecosystems. At the same time they are among the world's most threatened ecosystems because of the pervasiveness of dams, levees and other factors such as rapid spreading of non-native species. Hence, floodplains are ideal systems to study ecological impacts of multiple stressors at the local, regional and catchment scale.

2. Concepts such as the subsidy-stress hypothesis and the stress-induced community tolerance concept have been formulated to study the effect of stressors on aquatic and terrestrial ecosystems, as well as on their functional linkages.

3. Riverine floodplains are pulsed ecosystems with distinct flow, sediment, resource and thermal pulses and thereby creating distinct 'windows of ecological opportunity'. Human modifications that truncate or amplify theses pulses will have cascading effects on river-floodplain interactions by shifting the thresholds of connectivity, resilience or resistance ? causing drastic regime shifts.

4. Most aquatic insects and pond-breeding amphibians have complex life cycles with aquatic and terrestrial stages. They are exposed to different stressors in their aquatic and terrestrial realm. Because most life history functions of aquatic insects are restricted to a short terrestrial period, we need to fully integrate the 'airscape' into the future management of river-floodplain ecosystems.

5. Riverine floodplains integrate and accumulate multiple stressors at the catchment level, as reflected by distinct catchment fingerprints. Based on the European Catchment Data Base we provide spatially explicit information on multiple stressors; a key prerequisite for setting priorities in conservation and management planning.

6. Thematic implications: the management of stressed river and floodplain ecosystems is a major challenge for the near future and water managers worldwide. Management approaches need to be adaptive and embedded within a catchment-wide concept to cope with upcoming pressures originating from global change.

Link

http://dx.doi.org/10.1111/j.1365-2427.2009.02371.x

Townsend, Colin R., et al. "Scale and the Detection of Land-use Effects on Morphology, Vegetation and Macroinvertebrate Communities of Grassland Streams." ***Freshwater Biology*** **49.4 (2004): 448-62.**

Abstract

1. Land-use studies are challenging because of the difficulty of finding catchments that can be used as replicates and because land-use effects may be obscured by sources of variance acting over spatial scales smaller than the catchment. To determine the extent to which land-use effects on stream ecosystems are scale dependent, we designed a whole-catchment study of six matched pairs (pasture versus native tussock) of second-order stream catchments, taking replicate samples from replicate bedforms (pools and riffles) in each stream.

2. Pasture streams had a smaller representation of endemic riparian plant species, particularly tussock grasses, higher bank erosion, a somewhat deeper layer of fine sediment, lower water velocities in riffles, less moss cover and higher macroinvertebrate biodiversity. At the bedform scale, suspendable inorganic sediment (SIS) was higher in pools than riffles and in pasture streams there was a negative relationship between SIS and the percentage of the bed free of overhanging vegetation. Differences between stream reaches (including any interactions between land use and stream pair) were significant for SIS, substrate depth and characteristics of riparian vegetation. There were also significant differences between replicate bedforms in the same stream reaches in percentage exotic species in overhanging vegetation, percentage moss cover, QMCI (Quantitative Macroinvertebrate Community Index ? a macroinvertebrate-based stream health index) and macroinvertebrate density.

3. Significant differences among stream reaches and among replicate bedform units within the same reach, as well as interactions between these spatial units and land-use effects, are neither trivial nor 'noise' but represent real differences among spatial units that typically are unaccounted for in stream studies. Our multi-scale study design, accompanied by an investigation of the explanatory power of different factors operating at different scales, provides an improved understanding of variability in nature.

Link

http://dx.doi.org/10.1111/j.1365-2427.2004.01192.x

Townsend, Colin R., Mike R. Scarsbrook, and Sylvain Dolédec. "Quantifying Disturbance in Streams: Alternative Measures of Disturbance in Relation to

Macroinvertebrate Species Traits and Species Richness." *Journal of the North American Benthological Society* **16.3 (1997): pp. 531-544.**

Abstract

Appropriate tests of disturbance theory require that disturbance is defined and measured in an organism-related sense. We quantified 7 measures of disturbance, 3 dealing with the pattern of disturbance of the stream bed (assessed using painted tracer particles), 3 dealing with aspects of discharge variation and 1 being a subjective composite measure of stream channel stability (Pfankuch's index). Hypotheses relating to invertebrate taxon richness (maximal at intermediate levels of disturbance) and the representation of particular insect species traits (assemblages in more disturbed sites contain higher percentages of individuals possessing high adult mobility and streamlined-flattened larval morphology) were both supported when disturbance was measured in terms of bed movement but generally not when measured in terms of discharge variation. When disturbance was estimated by Pfankuch's index, species trait predictions were supported but the taxon richness prediction was not. A co-inertia analysis, searching for a co-structure between our environmental and faunistic data sets, allowed us to distinguish taxa that apparently are resistant to bed movement from taxa that appear to be resistant to flow variations; this more detailed analysis indicates that the most appropriate measure of disturbance may vary even among quite closely related taxa. The construction of a comprehensive theory of disturbance in streams requires that disturbance is quantified in a way that allows both multi-site and multi-study comparisons. The painted-particle approach, described here, has the potential to permit such standarized comparative studies.

Link

http://www.jstor.org/stable/1468142

***Townsend, Colin R., S. Sebastian Uhlmann, and Christoph D. Matthaei. "Individual and Combined Responses of Stream Ecosystems to Multiple Stressors."** *Journal of Applied Ecology* **45.6 (2008): 1810-9.**

Abstract

1. Managers must understand the effects of stressors on ecosystems in order to identify thresholds of harm but, to be meaningful, thresholds will usually need to be defined for situations where multiple stressors are operating. *

2. We investigated the individual and combined effects of the principal stressors (nutrient concentration and streambed fine sediment cover) operating in native grassland streams converted to pasture in New Zealand, using two different approaches: a survey of 32 small streams and an experiment involving nine streams where the stressors were manipulated in a factorial design. We investigated the consequences for populations of benthic invertebrates and for the structure of communities, including taxon richness and the representation of species traits. *

3. Up to half the taxa and most community metrics responded to at least one stressor. Our results suggest that in these streams, an increase in fine sediment loading from anthropogenic causes had more widespread effects than augmented nutrient concentrations. Of most significance is our finding, both from the survey and, in particular, the experiment, of a variety of complex interactions among the stressors. *

4. Synthesis and applications. The development of indices of stream health that distinguish the effects of sediment from those of nutrients should help prioritize catchment management actions. Of more general importance is our finding that the consequences of stressors are often unpredictable on the basis of knowledge of single effects; if managers only consider the effects of individual stressors, their assessment of risk may be higher or lower than reality.

Link

http://dx.doi.org/10.1111/j.1365-2664.2008.01548.x

***** **--- Understanding Multiple Environmental Stresses: Report of a Workshop. The National Academies Press, 2007.**

The research of the last decade has demonstrated that ecosystems and human systems are influenced by multiple factors, including climate, land use, and the by-products of resource use. Understanding the net impact of a suite of simultaneously occurring environmental changes is essential for developing effective response strategies. Using case studies on drought and a wide range of atmosphere-ecosystem interactions, a workshop was held in September 2005 to gather different perspectives on multiple stress scenarios. The overarching lesson of the workshop is that society will require new and improved strategies for coping with multiple stresses and their impacts on natural socioeconomic systems. Improved communication among stakeholders; increased observations (especially at regional scales); improved model and information systems; and increased infrastructure to provide better environmental monitoring, vulnerability assessment, and response analysis are all important parts of moving toward better understanding of and response to situations involving multiple stresses. During the workshop, seven near-term opportunities for research and infrastructure that could help advance understanding of multiple stresses were also identified.

Link

http://dels.nas.edu/Workshop-Summary/Understanding-Responding-Multiple-Environmental/11748

Underwood, A. J. "The Analysis of Stress in Natural Populations." *Biological Journal of the Linnean Society* **37.1-2 (1989): 51-78.**

Abstract

Populations usually persist despite environmental variations. Experimental analysis of responses to stress must include distinction between potential stresses (environmental perturbations that might not cause stress) and actual stress (phenomena that cause a response by the population). This is made difficult by large temporal fluctuations in abundances of many organisms. Monitoring can measure this variability but is insufficient to predict the potential impact of most stresses. Experimental analyses of stresses are also made difficult by differences among populations in their inertia (lack of response to perturbation), resilience (magnitude of stresses from which a population can recover) and stability (rate of recovery following a stress). These attributes of populations cause a range of responses to intermittent, temporary and acute (or 'pulse') stresses and to long-term, chronic ('press') disturbances. The timing, magnitude and order of stresses can cause different responses by populations. Synergisms between simultaneous or successive stresses can also have unpredictable effects on populations and cause complexity in interpretations of patterns of competition and predation. Experimental manipulations are needed to understand the likely effect of environmental disturbances on populations. The appropriate experiments are those designed to measure the effects of different types, magnitudes and frequencies of simulated stresses. These will be more revealing than the more common experimental analyses used to determine why and how observed changes in abundances of populations are caused by existing stresses.

Link

http://dx.doi.org/10.1111/j.1095-8312.1989.tb02005.x

***USEPA, 2000 US Environmental Protection Agency (USEPA). *Stressor Identification Guidance Document*. Tran. Office of Water. Washington, DC:, 2000.**

Abstract

The SI guidance document describes the organization and analysis of available evidence to determine the cause of biological impairment. The document does not directly address biological assessment, impairment detection, source allocation, management actions, or data collection, although these activities interact with SI in significant ways. This document is intended to guide water resource managers through the Stressor Identification process.

Link

http://water.epa.gov/scitech/swguidance/waterquality/sandards/loader.cfm?csModule=security/getfile&PageID=30359

Van Der Geest, Harm G., et al. "Combined Effects of Lowered Oxygen and Toxicants (Copper and Diazinon) on the Mayfly Ephoron Virgo." *Environmental Toxicology and Chemistry* 21.2 (2002): 431-6.

Abstract

In many large European rivers, the number of typical riverine insect species, such as mayflies, stoneflies, and caddisflies, is greatly reduced compared to historic records. This can no longer be explained by high concentrations of a relatively small number of dominant toxicants since many rivers have changed from heavily contaminated systems with a few selected key toxicants to systems with a complex contamination. This contamination consists of many substances in low concentrations coinciding with other unfavorable conditions, such as low oxygen concentrations. It was hypothesized that the joint adverse effects of such multiple stressors may be a steering factor in the distribution of riverine insect species. The aim of this study was therefore to determine the combined effects of toxicants and oxygen depletion. To this purpose, larvae of the indigenous riverine mayfly Ephoron virgo were exposed to two different model toxicants, copper and diazinon, under normoxia and hypoxia (50% air saturation) conditions. The median effective concentrations for mortality for copper were significantly lower in the hypoxia treatments than in the normoxia treatments. For diazinon, no differences were observed between two treatments differing in dissolved oxygen levels, and therefore we argue that interactions between multiple stressors may be compound specific. It is concluded that the combination of toxicants and lowered oxygen may have a stronger impact than can be expected based on the adverse effects of the individual factors and that standard toxicity tests may be insufficient alone to determine the impact of human activities on the ecological state of riverine communities. Instead, attention needs to be paid to more environmentally realistic nonoptimal conditions in toxicity testing to adequately fulfill the needs of ecological recovery programs.

Link

http://dx.doi.org/10.1002/etc.5620210228

Van Sickle, John, et al. "Using Relative Risk to Compare the Effects of Aquatic Stressors at a Regional Scale."** ***Environ Manage **38 (2006): 1020-30.**

Abstract

The regional-scale importance of an aquatic stressor depends both on its regional extent (i.e., how widespread it is) and on the severity of its effects in ecosystems where it is found. Sample surveys, such as those developed by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP), are designed to estimate and compare the extents, throughout a large region, of elevated conditions for various aquatic stressors. In this article, we propose relative risk as a complementary measure of the severity of each stressor's effect on a response variable that characterizes aquatic ecological condition. Specifically, relative risk measures the strength of association between stressor and response variables that can be classified as either "good" (i.e., reference) or "poor" (i.e., different from reference). We present formulae for estimating relative risk and its confidence interval, adapted for the unequal sample inclusion probabilities employed in EMAP surveys. For a recent EMAP survey of streams in five Mid-Atlantic states, we estimated the relative extents of eight stressors as well as their relative risks to aquatic macroinvertebrate assemblages, with assemblage condition measured by an index of biotic integrity (IBI). For example, a measure of excess sedimentation had a relative risk of 1.60 for macroinvertebrate IBI, with the meaning that poor IBI conditions

were 1.6 times more likely to be found in streams having poor conditions of sedimentation than in streams having good sedimentation conditions. We show how stressor extent and relative risk estimates, viewed together, offer a compact and comprehensive assessment of the relative importance's of multiple stressors.

Link

http://www.epa.gov/bioindicators/pdf/Vansickle_et_al_2006_UsingRelativeRisktoCompareEffectsofAquaticStressorsataRegionalScale.pdf

Vinebrooke, Rolf D., et al. "Impacts of Multiple Stressors on Biodiversity and Ecosystem Functioning: The Role of Species Co-Tolerance."** ***Oikos **104.3 (2004): 451-7.**

Abstract

Ecosystem resistance to a single stressor relies on tolerant species that can compensate for sensitive competitors and maintain ecosystem processes, such as primary production. We hypothesize that resistance to additional stressors depends increasingly on species tolerances being positively correlated (i.e. positive species co-tolerance). Initial exposure to a stressor combined with positive species co-tolerance should reduce the impacts of other stressors, which we term stress-induced community tolerance. In contrast, negative species co-tolerance is expected to result in additional stressors having pronounced additive or synergistic impacts on biologically impoverished functional groups, which we term stress-induced community sensitivity. Therefore, the sign and strength of the correlation between species sensitivities to multiple stressors must be considered when predicting the impacts of global change on ecosystem functioning as mediated by changes in biodiversity.

Link

http://www2.biology.ualberta.ca/faculty/rolf_vinebrooke/uploads/abstracts/Oikos2004.pdf

Vörösmarty, Charles J., And Dork Sahagian. "Anthropogenic Disturbance of the Terrestrial Water Cycle." ***Bioscience*** **50.9 (2000): 753.**

Abstract

The terrestrial water cycle plays a central role in the climate, ecology, and biogeochemistry of the planet. Mounting historical evidence for the influence of greenhouse warming on recent climate, and modeling projections into the future, highlight changes to the land-based water cycle as a major global change issue (Houghton et al. 1995, Watson et al. 1996, SGCR 1999). Disturbance of the hydrologic cycle has received significant attention with respect to land–atmosphere exchanges, plant physiology, net primary production, and the cycling of major nutrients (Foley et al. 1996, Sellers et al. 1996, McGuire et al. 1997). Changes in land use are also recognized as critical factors governing the future availability of fresh water (Chase et al. 2000). Another important but seldom articulated global change issue is direct alteration of

the continental water cycle for irrigation, hydroelectricity, and other human needs. Although the scope and magnitude of water engineering today are colossal in comparison with preindustrial times, most of the very same activities—irrigation, navigation enhancement, reservoir creation—can be traced back several thousand years in the Middle East and China. Stabilization of water supply has remained a fundamental preoccupation of human society and is a key security concern for most nations. Reducing flood hazard, enhancing food security, and redirecting runoff from water-rich to water-poor areas continue to provide a major challenge to our engineering infrastructure. In this article we address three issues. First, we document the nature and magnitude of direct human alteration of the terrestrial water cycle, specifically through construction of engineering works for water resource management. We focus on the redistribution of freshwater among major storage pools and the corresponding changes to continental runoff. Second, we explore some of the impacts of this disturbance on drainage basins, river systems, and land-to-ocean linkages. Finally, we review key uncertainties regarding our current understanding of human–water interactions at the global scale and make suggestions on potentially useful avenues for future research.

Link

http://caliber.ucpress.net/doi/abs/10.1641/0006-3568%282000%29050%5B0753%3AADOTTW%5D2.0.CO%3B2?select23=Choose&journalCode=bisi

Wang, Lizhu, and Paul Kanehl. "Influences of Watershed Urbanization and Instream Habitat on Macroinvertebrates in Cold Water Streams." ***JAWRA Journal of the American Water Resources Association*** **39.5 (2003): 1181-96.**

Abstract

We analyzed data from riffle and snag habitats for 39 small cold water streams with different levels of watershed urbanization in Wisconsin and Minnesota to evaluate the influences of urban land use and instream habitat on macroinvertebrate communities. Multivariate analysis indicated that stream temperature and amount of urban land use in the watersheds were the most influential factors determining macroinvertebrate assemblages. The amount of watershed urbanization was nonlinearly and negatively correlated with percentages of Ephemeroptera-Plecoptera-Trichoptera (EPT) abundance, EPT taxa, filterers, and scrapers and positively correlated with Hilsenhoff biotic index. High quality macroinvertebrate index values were possible if effective imperviousness was less than 7 percent of the watershed area. Beyond this level of imperviousness, index values tended to be consistently poor. Land uses in the riparian area were equal or more influential relative to land use elsewhere in the watershed, although riparian area consisted of only a small portion of the entire watershed area. Our study implies that it is extremely important to restrict watershed impervious land use and protect stream riparian areas for reducing human degradation on stream quality in low level urbanizing watersheds. Stream temperature may be one of the major factors through which human activities degrade cold-water streams, and management efforts that can maintain a natural thermal regime will help preserve stream quality.

Link

http://dx.doi.org/10.1111/j.1752-1688.2003.tb03701.x

Williams, Adrian E., and Robert E. Hecky. "Invasive Aquatic Weeds and Eutrophication: The Case of Water Hyacinth in Lake Victoria." ***Restoration and Management of Tropical Eutrophic Lakes*** **(2005): 187-225.**

Abstract

Invasive aquatic weeds have spread throughout the world's waterways because of anthropogenic activities. The three most problematic species are water hyacinth, floating water fern and water lettuce. With the potential to double in biomass in a matter of days and the ability to migrate easily due to their free-floating vegetative form, they can successfully colonise new habitats, form dense mats along shorelines and displace native vegetation. In doing so they effect ecological processes within lakes and decrease biodiversity. Moreover for human populations living around such lakes they reduce access and quality of available drinking and irrigation water, prevent fishermen from making a living, clog water intakes at hydro-electric dams, increase vector-borne diseases and generally lead to an increase in human suffering. Cultural eutrophication of lakes is also a major problem around the world and can amplify the problem of nuisance floating plants. Weed growth can expand rapidly if loading of nutrients such as nitrogen and phosphorus increases. In Africa there are many examples of eutrophication leading to elevated weed biomass and the subsequent problems that this brings. In Lake Victoria, East Africa, water hyacinth was a major problem in the 1990s that has now largely subsided. However there are signs that eutrophication, as a result of anthropogenic changes in land use, is still2increasing. At minimum this will likely maintain the presence of water hyacinth within the lake but it also has the potential to bring about a resurgence to nuisance status. If this occurs then the human suffering experienced could be above and beyond that seen during the 1990s. Methods to manage water hyacinth are available. These include physical, chemical and biological forms of control. However for the long-term sustainability of Lake Victoria, including the control of water hyacinth, only improved land, air and watershed management can provide the solution to reducing eutrophication and the potential of water hyacinth outbreaks. The measures needed to effect the changes necessary for nutrient control require a massive financial injection. The countries bordering Lake Victoria have a direct responsibility towards it and should contribute in every way to its restoration as the result of non-action will be regionally devastating. However there are also implications for the global economy therefore solutions also need to involve a wider arena.

Link

http://freespace.virgin.net/ae.williams/New/2005%20Tropical%20Eutrophic%20Lakes%20Their%20Restoration%20and%20Management%20-%20Invasive%20aquatic%20weeds%20and%20eutrophication%20The%20culmination%20in%20Lake%20Victoria.pdf

Winter, Thomas C. "Ground Water and Surface Water: The Linkage Tightens, but Challenges Remain." ***Hydrological Processes*** **15.18 (2001): 3605-6.**

Abstract

Hydrologists have recognized for more than a century that groundwater and surface water are closely linked, but for most of that time studies of their interaction were carried out largely by single disciplines. This is slowly changing, however, as the need for integrated studies involving many disciplines is becoming more evident. For many years, development of water resources for water supply drove hydrologic research. Surface-water hydrologists developed analytical methods and statistical tools to determine stream flow characteristics. These tools were then used to design projects to develop streams for water supply. Hydrologists knew that base flow in streams was ground-water discharge, but they generally were unconcerned about understanding the ground-water flow paths that carried the water to the streams—they just wanted to know if the water was going to be there for human use. Ground-water hydrologists developed analytical methods and statistical tools to determine aquifer characteristics. These tools were then used to design projects to develop aquifers for water supply. To groundwater hydrologists, surface water was a potential source to groundwater. They knew that if a well was placed near enough to a surface water body, surface water could be drawn to the well, with the added benefit of having it filtered along the way. Indeed, in the case of wetlands, it was common practice to suggest that water could be "salvaged "by withdrawing enough ground water near wetlands to lower the water table below the root zone of aquatic plants, thus gaining "beneficial use "of water that would otherwise be "lost "to evapotranspiration. There was little concern for what these groundwater development practices might do to stream, lake, and wetland ecosystems. With this discipline-oriented thinking, in which surface water and ground water were considered separate resources, it was not surprising that many states issued, and continue to issue, surface water and ground-water permits separately. As a result, the total water resource has been over allocated in many states. In addition to the water allocation problem, two other scientific developments have occurred over the past few decades that have affected how scientists and water managers viewed the interaction of groundwater and surface water. One was the increased appreciation of ground-water flow systems as an important link in the hydrologic cycle, and the other was the increased appreciation of ground water as an important component of some aquatic ecosystems.

Link

http://onlinelibrary.wiley.com/doi/10.1002/hyp.504/pdf

Yesertener, Cahit. "Australian Journal of Water Resources - Impacts of Climate, Land and Water Use on Declining Groundwater Levels in the Gnangara Groundwater Mound, Perth, Australia (Engineering Collection) ." ***Australian Journal of Water Resources*** **8.2 (2005): 143-52.**

Abstract

The Gnangara Groundwater Mound, Perth, is an important source of water for metropolitan water supply, irrigated horticulture, and also for maintenance of wetland ecosystems. Wetland and groundwater levels on the Gnangara Groundwater Mound have been declining for the last thirty years. The declining water levels may be attributed to climate variation,

abstraction from the superficial and/or confined aquifers, and evapotranspiration and interception losses from pine plantations. A major change in rainfall has resulted in the annual average for the last 30 years being 10 to 15% below that of the previous 55 years. A relationship between groundwater level data for the Gnangara region and cumulative deviation from the mean rainfall (CDFM) was established. The CDFM technique was then applied to about 200 groundwater hydro graphs from the Gnangara Groundwater Mound to identify land and water use impacts on groundwater levels in the region. Multiple regression analysis was then used to validate the results. It has been concluded that reduced rainfall is the major cause of as much as 4 m decline since 1969. The cumulative long-term impact of abstraction in the Gnangara Groundwater Area was centred on the Pinjar Bore field, with declines of up to 2.5 m within a 5 km radius of the bore field. The Gnangara pine plantation has resulted in groundwater declines in the order of 2.4 m over the 1979-2001 period in areas where pines were particularly dense. Clearing before planting pines causes a rise of 1-3 m in groundwater levels for a 3-7 year period after clearing. Bush fires also have an impact, causing groundwater levels to rise about 0.5 to 2 m for a period of 2-4 years. Thinning of pines has some impact, causing groundwater levels to rise locally for a period of 1-3 years, depending on the degree of thinning.

Link

http://search.informit.com.au/documentSummary;dn=473742701452900;res=IELENG

Download restricted to pay-per-view

Yuan, Lester L., And Susan B. Norton. "Assessing the Relative Severity of Stressors at a Watershed Scale."** ***Environmental Monitoring and Assessment **98.1-3 : 323-49.**

Abstract

Water quality monitoring data are usually used independently to report on the condition of streams and watersheds. For example, watersheds are often rated as good, fair, or poor with regard to a single stressor or with regard to an index of biotic integrity. The utility of monitoring data may be enhanced by integrating stressor-response information with the observed stressor data, and reporting stressor levels in terms of their relative effects upon valued ecological resources. We estimated stressor-response relationships at the regional scale using data collected in the Eastern Cornbelt Plains Ecoregion of Ohio. Generalized additive models were used to visualize stressor-response relationships. Piecewise linear functions and simple linear functions were then used to parameterize the observed responses. Parameters derived from the regional models were used to scale observations of stressors in the Big Darby Creek watershed, OH. After scaling, stressors were compared in terms of their spatial distribution and in terms of the severity with which they influenced the biological endpoint of interest. Stressors most strongly associated with the current ecological condition of the watershed were identified. In the Big Darby Creek watershed, decreases in substrate quality were associated with the most severe decrements in biological condition. At smaller decrements in biological condition, three stressors were important: substrate quality, riparian quality, and increased concentrations of NOx.

Link

http://www.springerlink.com/content/n6563q8r8x32614u/

Zorrilla, P., et al. "Evaluation of Bayesian Networks as a Tool for Participatory Water Resources Management: Application to the Upper Guadiana Basin in Spain."** ***Ecology and Society **15.3 (2009): 12.**

Abstract

Stakeholder participation is becoming increasingly important in water resources management. In participatory processes, stakeholders contribute by putting forward their own perspective, and they benefit by enhancing their understanding of the factors involved in decision making. A diversity of modeling tools can be used to facilitate participatory processes. Bayesian networks are well suited to this task for a variety of reasons, including their ability to structure discussions and visual appeal. This research focuses on developing and testing a set of evaluation criteria for public participation. The advantages and limitations of these criteria are discussed in the light of a specific participatory modeling initiative. Modeling work was conducted in the Upper Guadiana Basin in central Spain, where uncontrolled groundwater extraction is responsible for wetland degradation and conflicts between farmers, water authorities, and environmentalists. Finding adequate solutions to the problem is urgent because the implementation of the EU Water Framework Directive requires all aquatic ecosystems to be in a "good ecological state" within a relatively short time frame. Stakeholder evaluation highlights the potential of Bayesian networks to support public participation processes.

Link

http://www.ecologyandsociety.org/vol15/iss3/